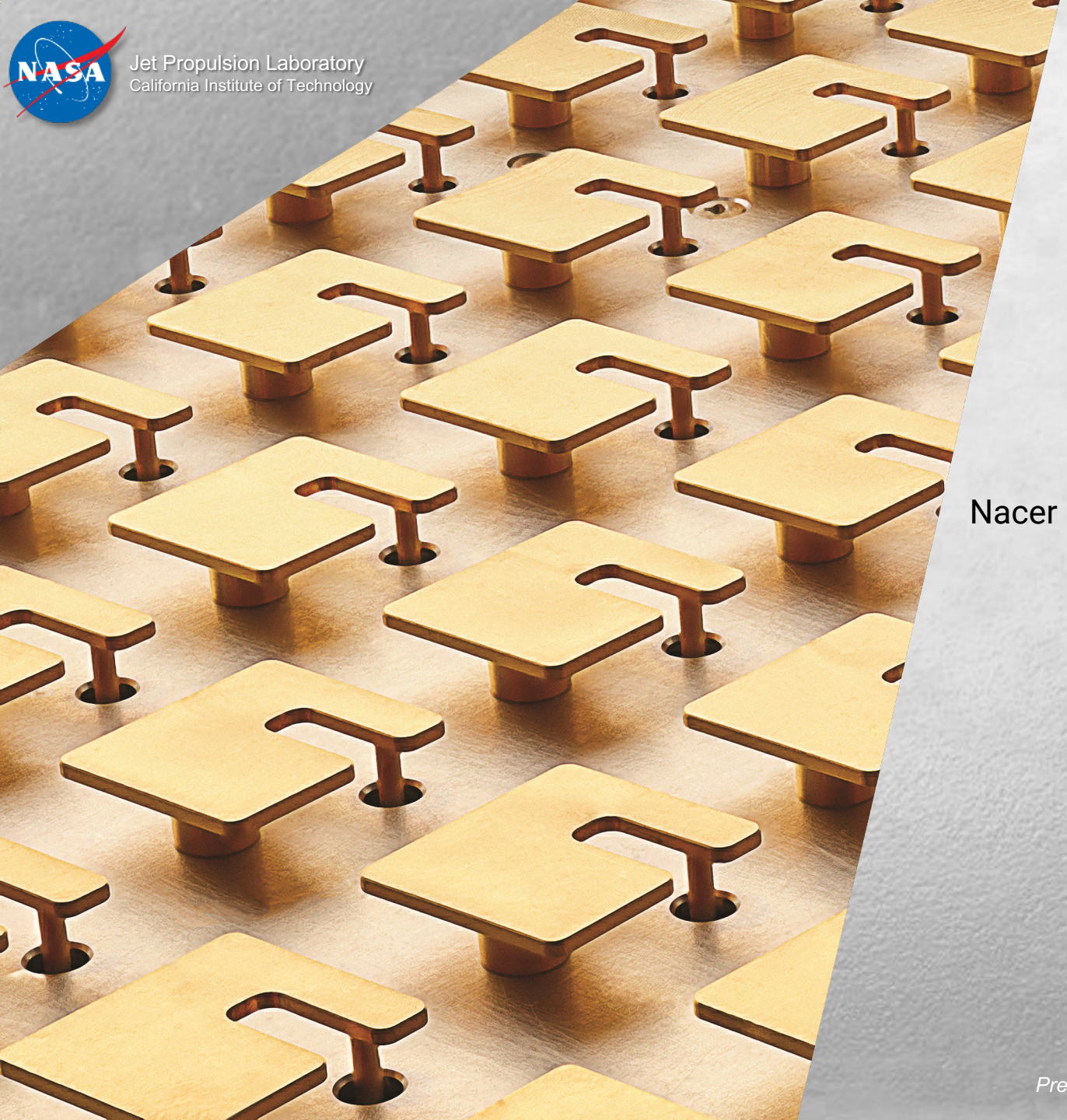

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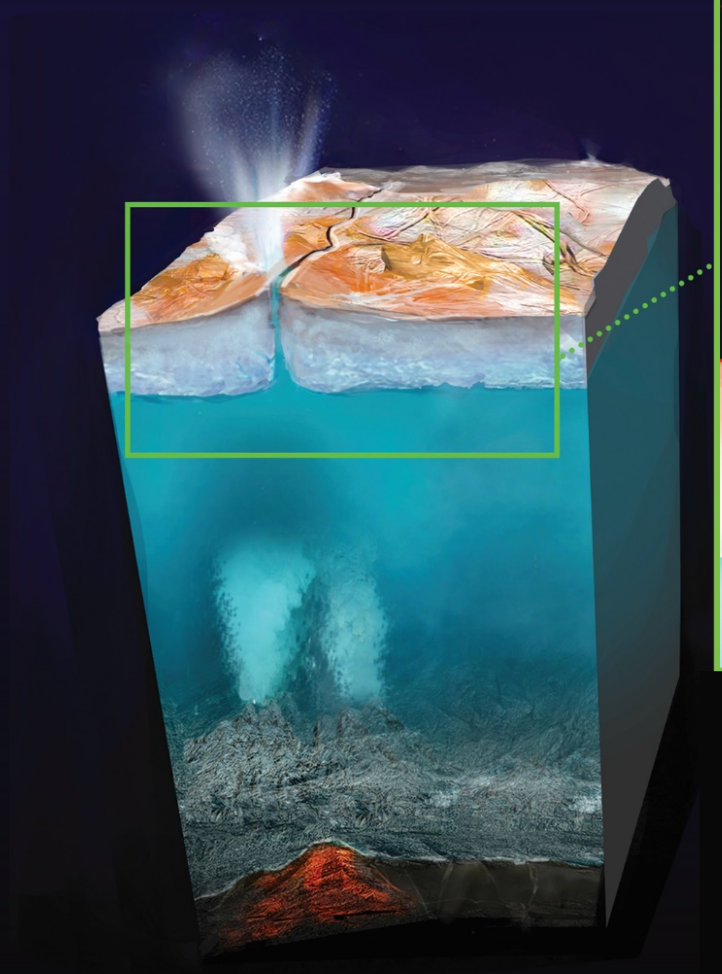
Qualification of a Highly Efficient Flat High Gain Antenna for the Potential Europa Lander

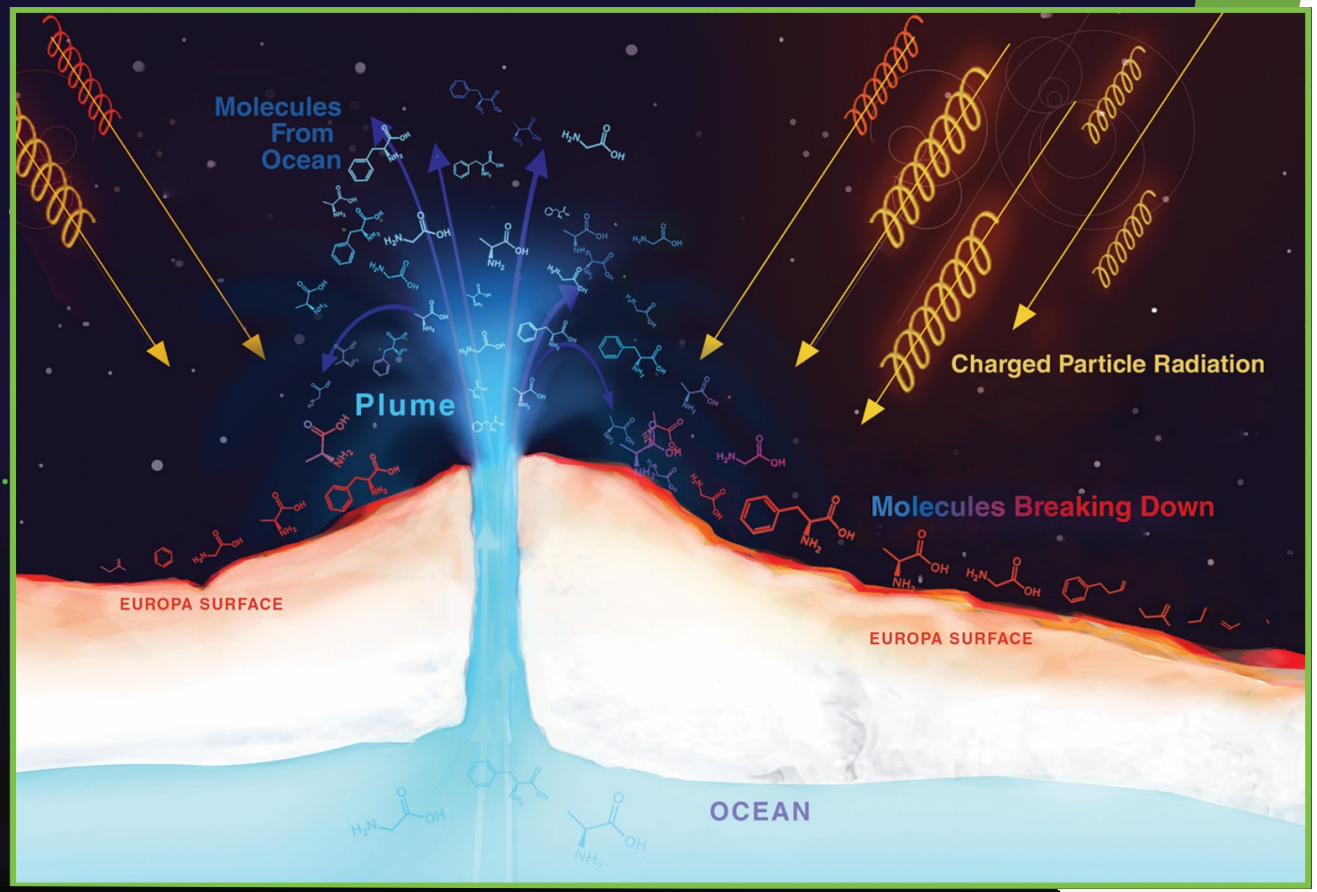
Nacer Chahat, John Luke Wolff, Heather Lim, and Polly Estabrook

NASA Jet Propulsion Laboratory / California Institute of Technology

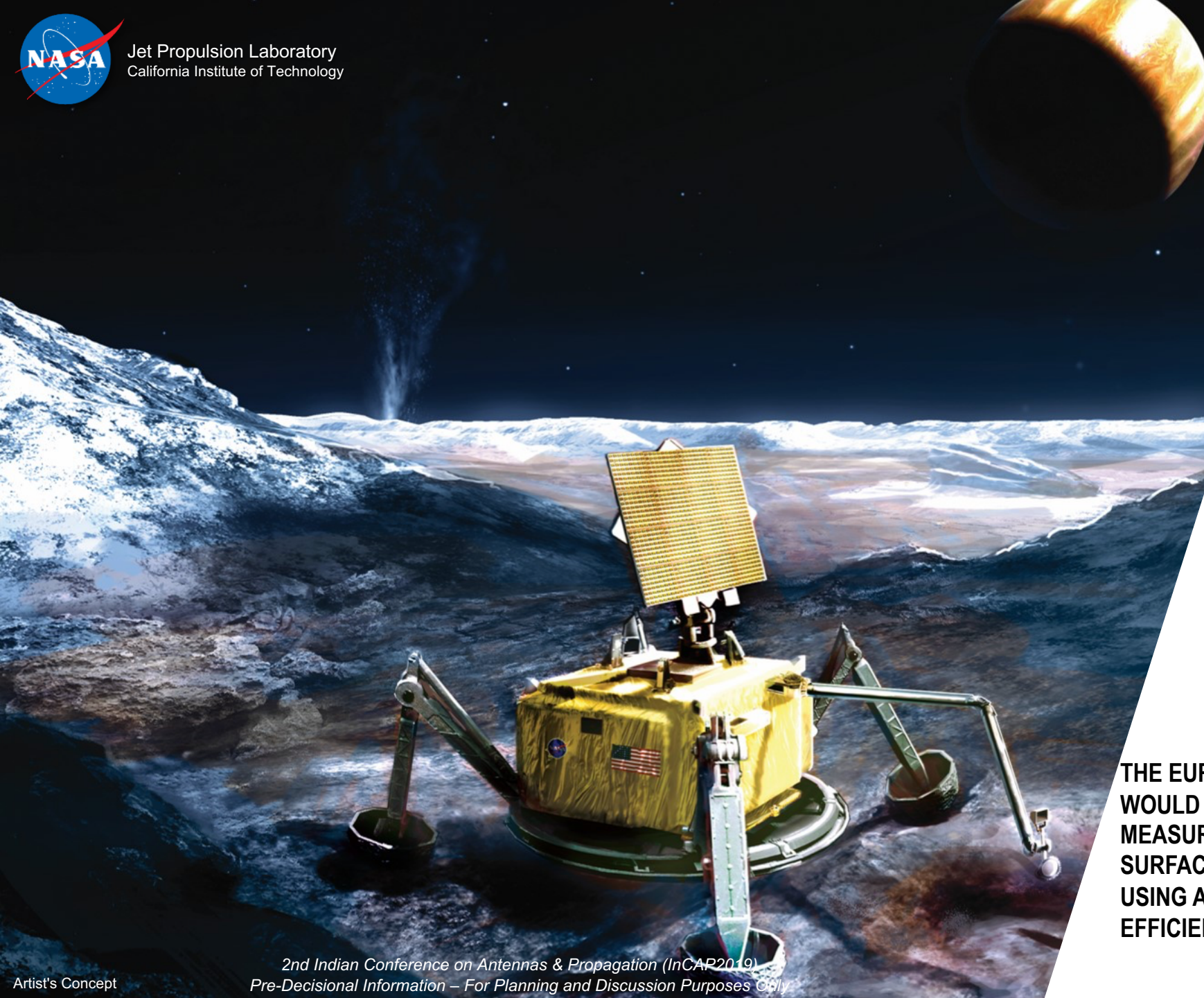
December 19, 2019

2nd Indian Conference on Antennas & Propagation (InCAP2019)
December 19-22, 2019 | Ahmedabad, India
Pre-Decisional Information – For Planning and Discussion Purposes Only

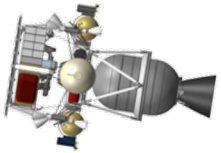


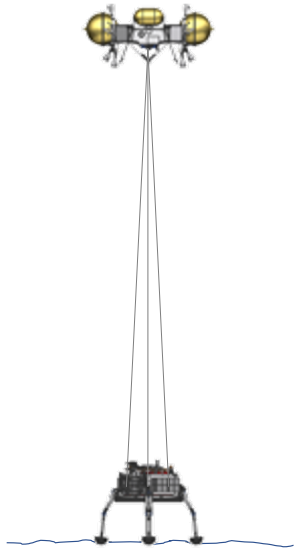


EUROPA HAS EMERGED AS ONE OF THE MOST LIKELY LOCATIONS IN THE SOLAR SYSTEM FOR POTENTIAL HABITABILITY



Artist's Concept





THE EUROPA LANDER WOULD CARRY OUT IN-SITU MEASUREMENTS ON THE SURFACE OF EUROPA USING A NEW HIGHLY EFFICIENT ANTENNA

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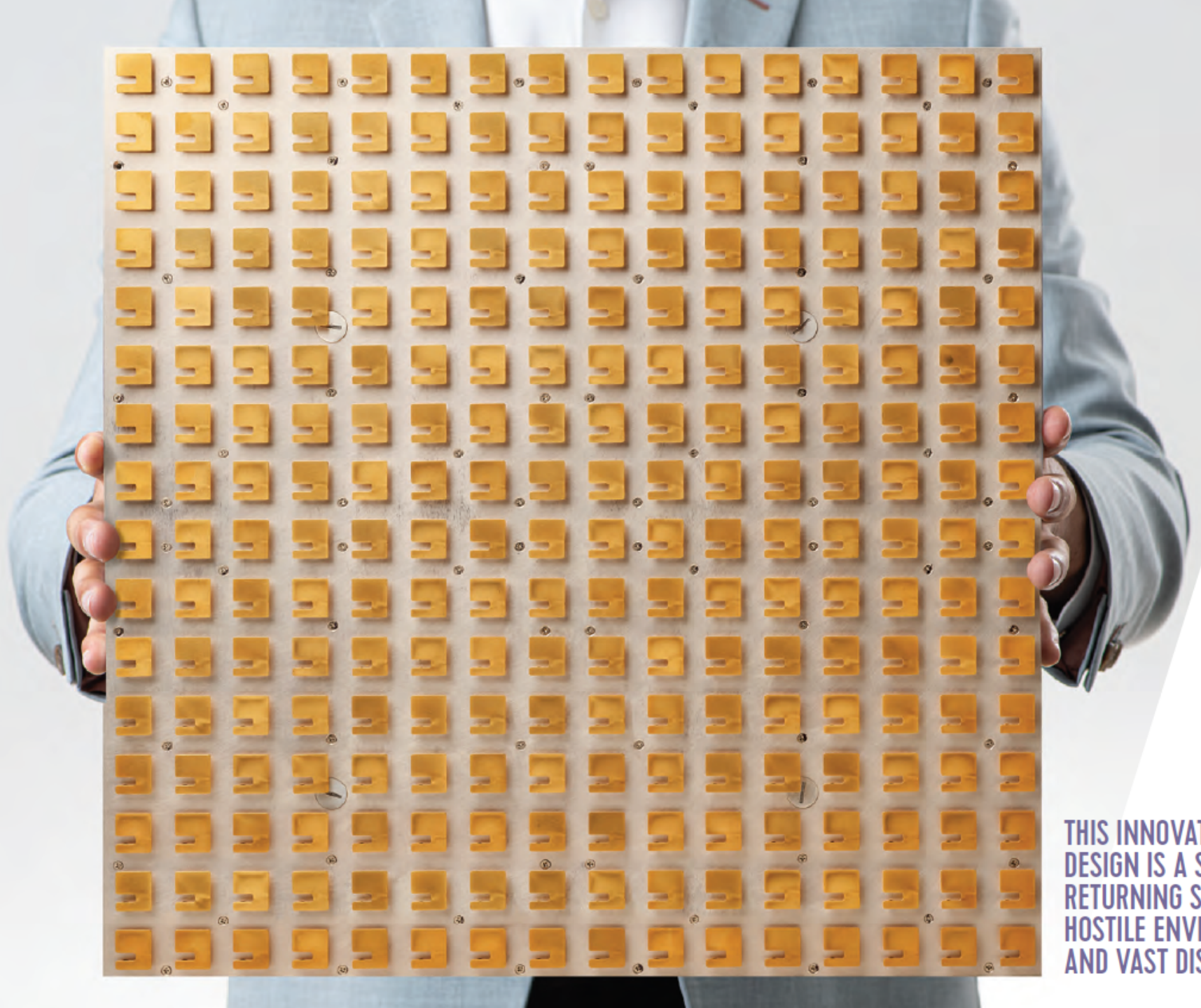
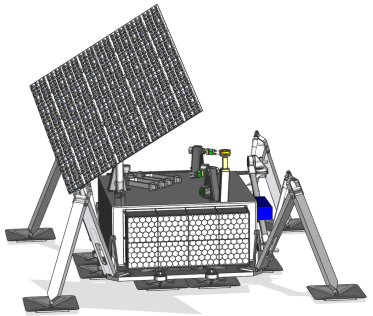
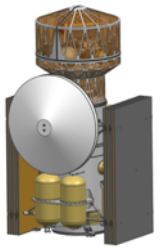
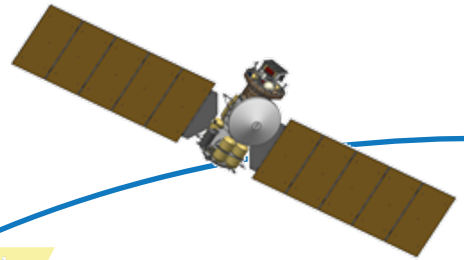


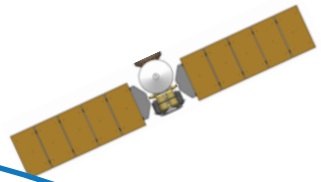


THIS INNOVATIVE ANTENNA DESIGN IS A SOLUTION FOR RETURNING SCIENCE FROM HOSTILE ENVIRONMENTS AND VAST DISTANCES

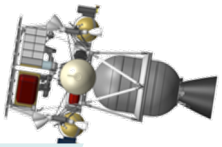




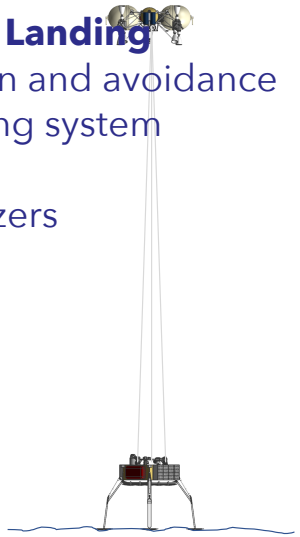
Cruise/Jovian Tour
- Jupiter Orbit Insertion: June 203
- Europa Landing: 2033



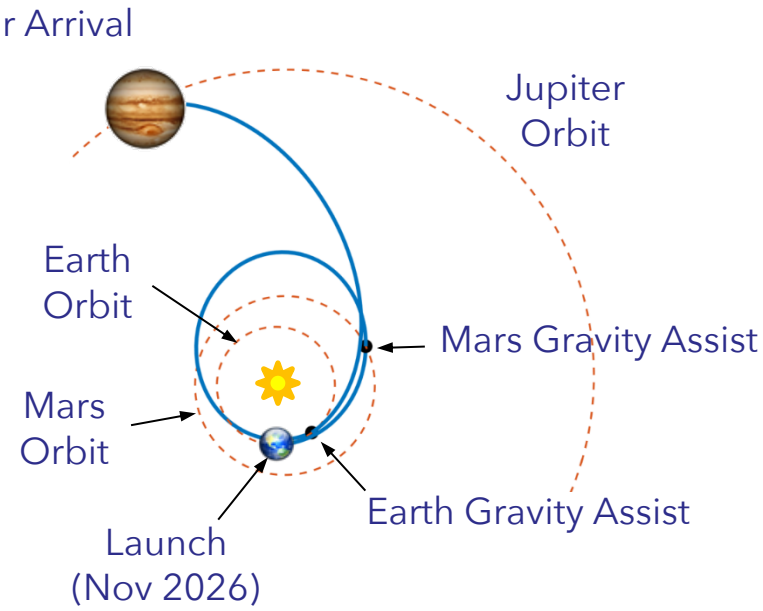
Carrier Stage
- 1.5 Mrad TID radiation exposure
- No longer an independent spacecraft
- Elliptical disposal orbit



Deorbit, Descent, Landing
- Hazard detection and avoidance
- Sky Crane landing system
- 100-m accuracy
- Adaptive stabilizers
- **DTE tones only**



Launch
- SLS Block 1B
- Nov 2026



Surface Mission
- Biosignature Science
- 20+ days
- 3 samples from 1 trench
- Direct to Earth Comm or Clipper (contingency)
- 1.5 Gbit data return
- 50 kWh battery
- 2.0 Mrad TID radiation exposure

Baseline mission concept

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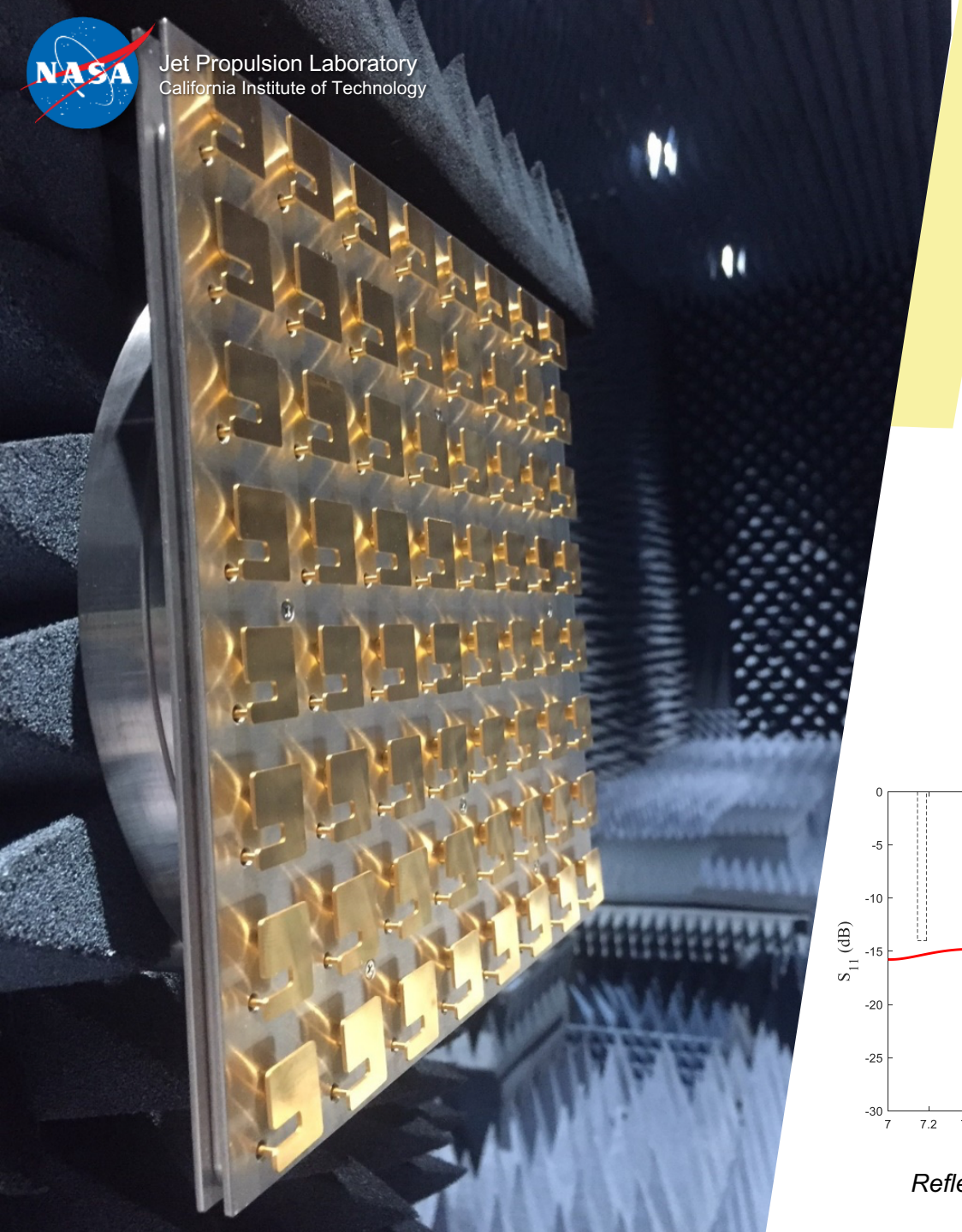
ENABLE DIRECT TO EARTH LINK COMMUNICATION BETWEEN THE LANDER AND THE DSN

CHALLENGES

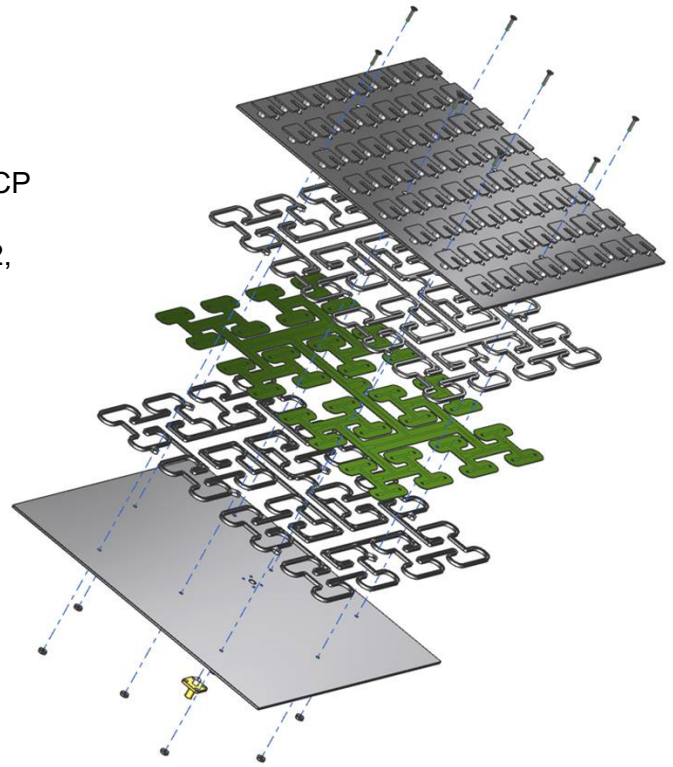
- Drastic stowage volume constraints requiring the antenna to be low profile
- Survivability in the harsh environment (high radiation levels, iESD, cryogenic temperature) requiring the antenna to be mostly made of metal
- High aperture efficiency* requirement (>80%) with RHCP at uplink and downlink frequency range

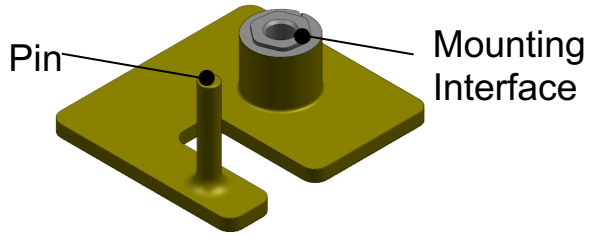
** Aperture efficiency is defined here as **the ratio of the realized gain of the antenna to its standard directivity.** The standard directivity is $4\pi A/\lambda_0^2$, where A the area of the antenna aperture and λ_0 is the free space wavelength. This defines how efficiently the area of an antenna is used.*

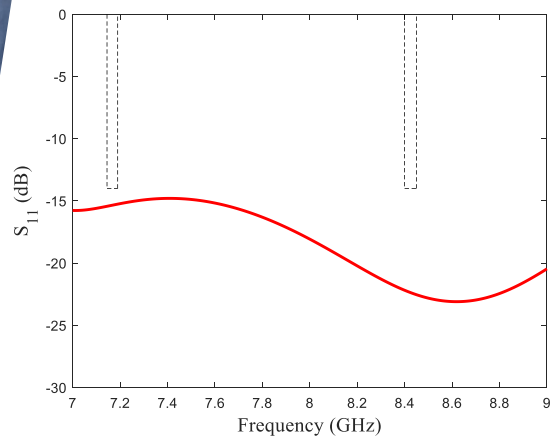


Patent pending: Chahat *et al.* “High-efficiency dual-band circularly-polarized antenna for harsh environment for Telecommunication”, filed on 12/18/17.

Publication: Chahat *et al.*, "All-Metal Dual-Frequency RHCP High-Gain Antenna for a Potential Europa Lander," *IEEE Transactions on Antennas and Propagation*, vol. 66, no. 12, pp. 6791-6798, Dec. 2018.

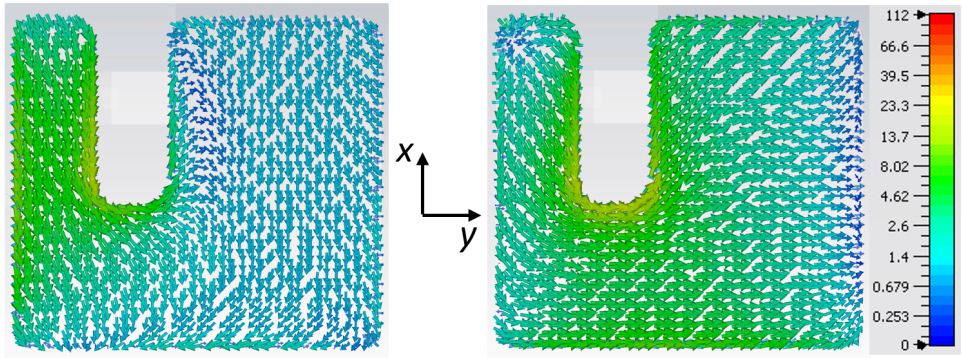






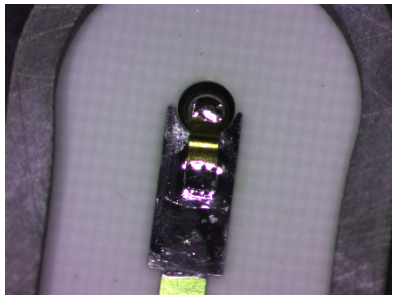
Reflection coefficient of unit cell

Surface current (A/m)



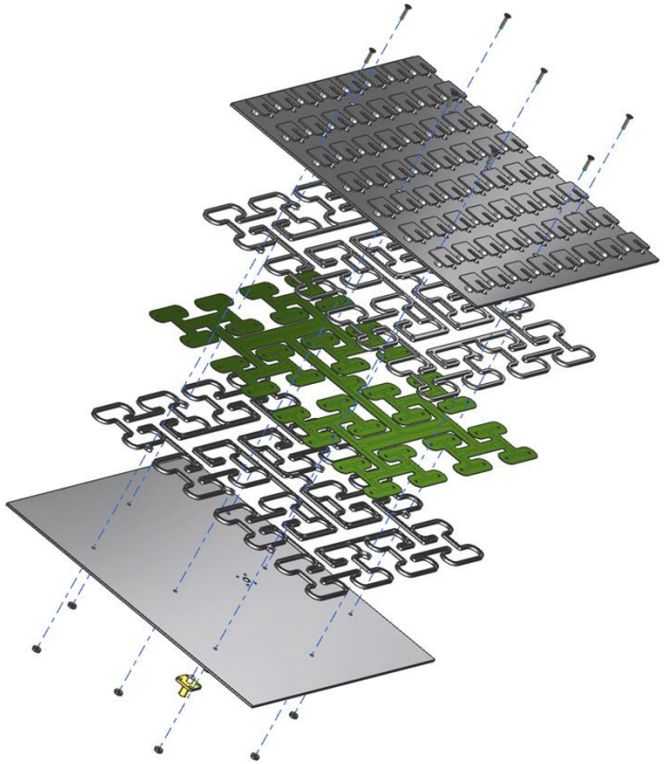
$\omega t = \Omega_0$

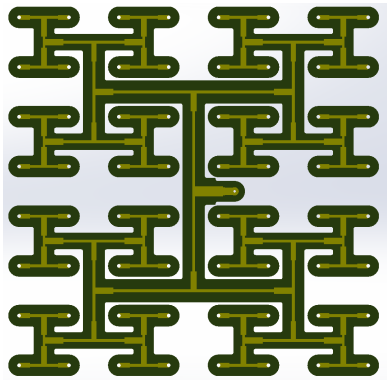
$\omega t = \Omega_0 + \pi/2$

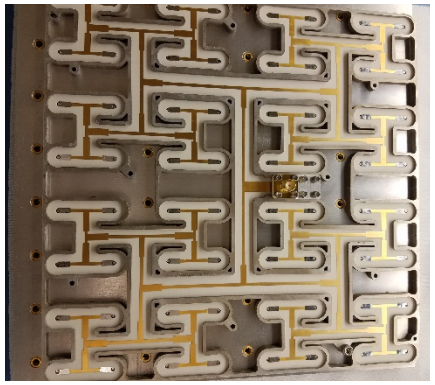


Solder pin to stripline (bottom side)

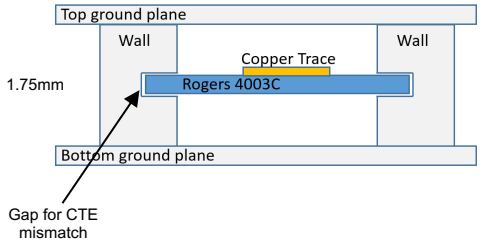
Pre tinned ribbon is used for stress relief

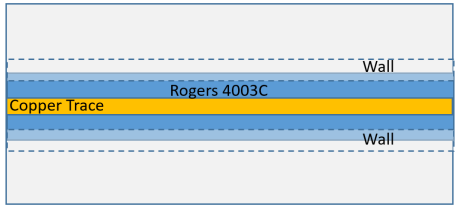


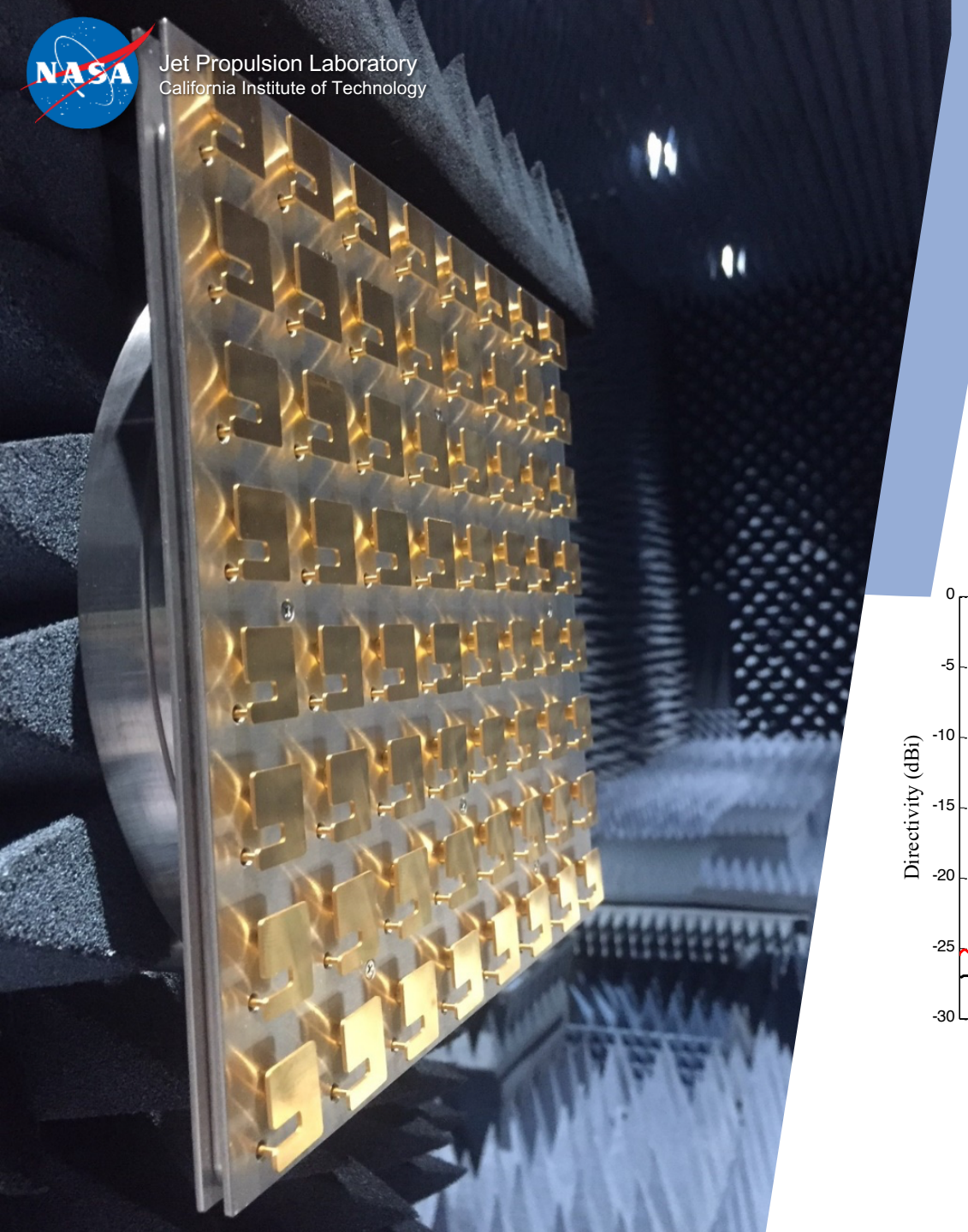


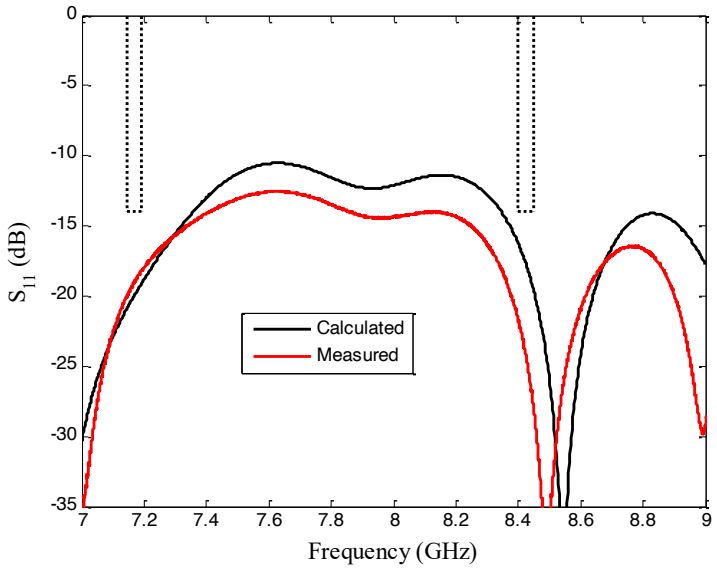


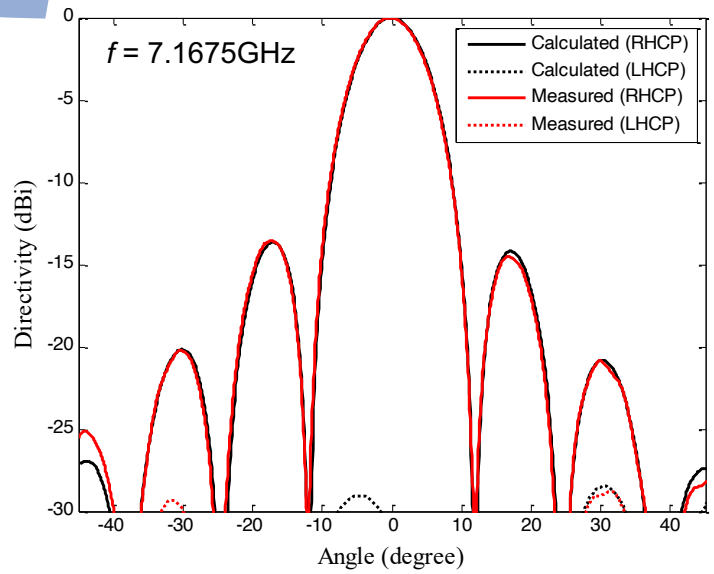
1-to-64 Power divider

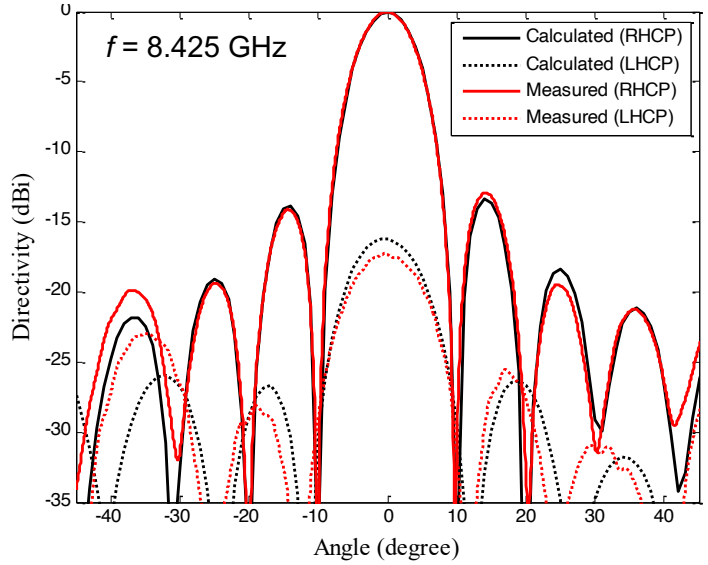






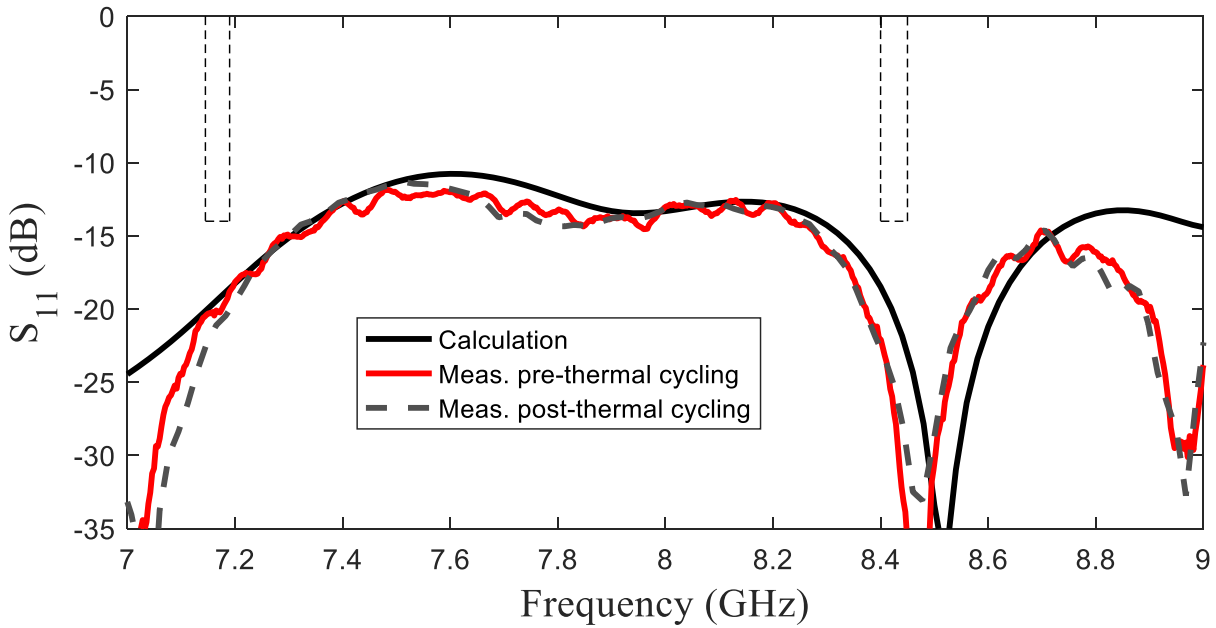


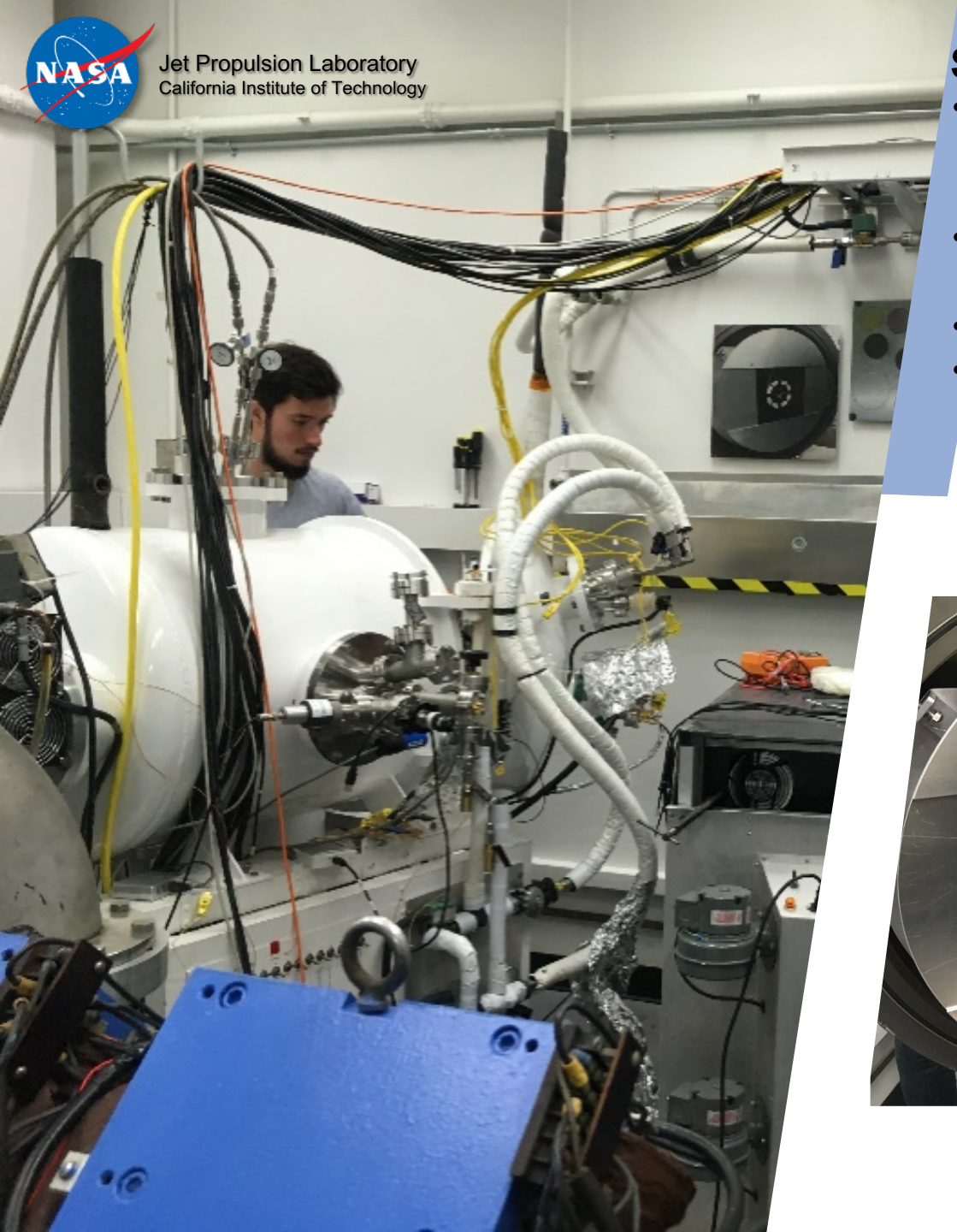




Gain at 7.1675Hz = 24.1 dBi ➔ Aperture efficiency ~ 84%
Gain at 8.425GHz = 25.3 dBi ➔ Aperture efficiency ~ 80%

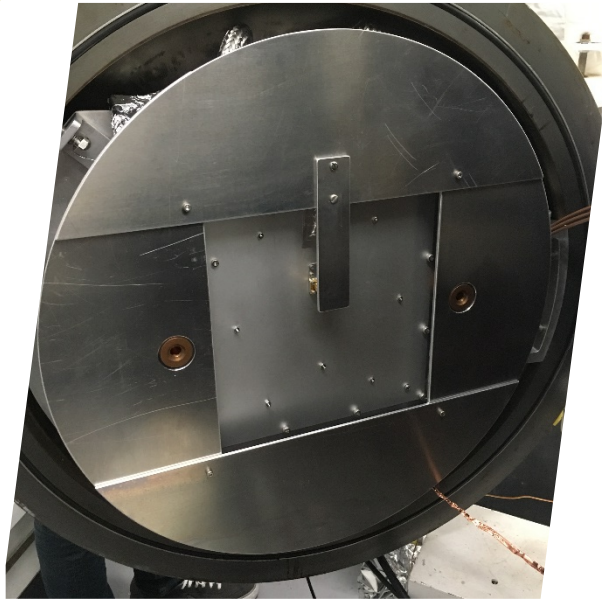
ANTENNA REFLECTION COEFFICIENT TESTED FROM -170C to +110C. THE ANTENNA EASILY SURVIVED THE THERMAL CYCLING.

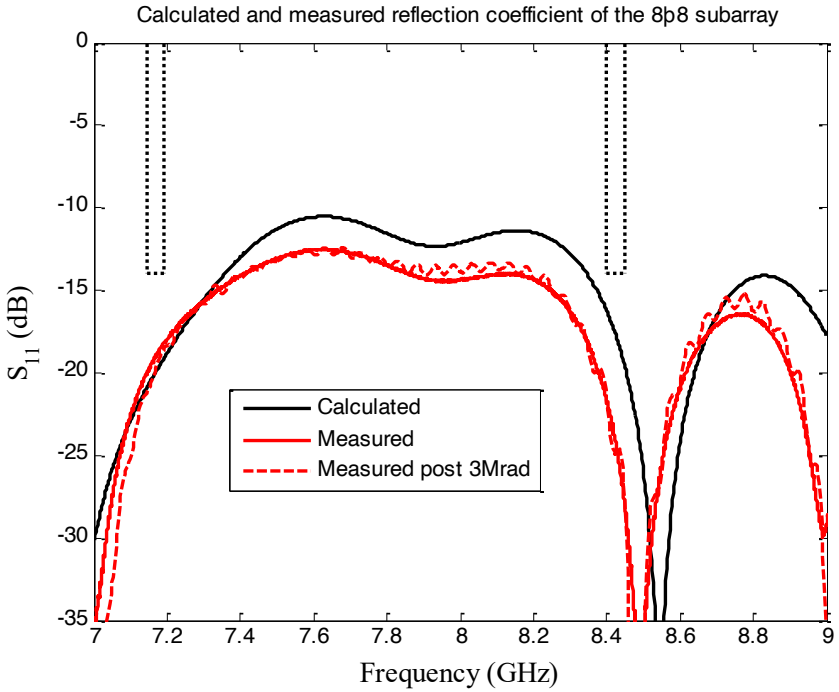


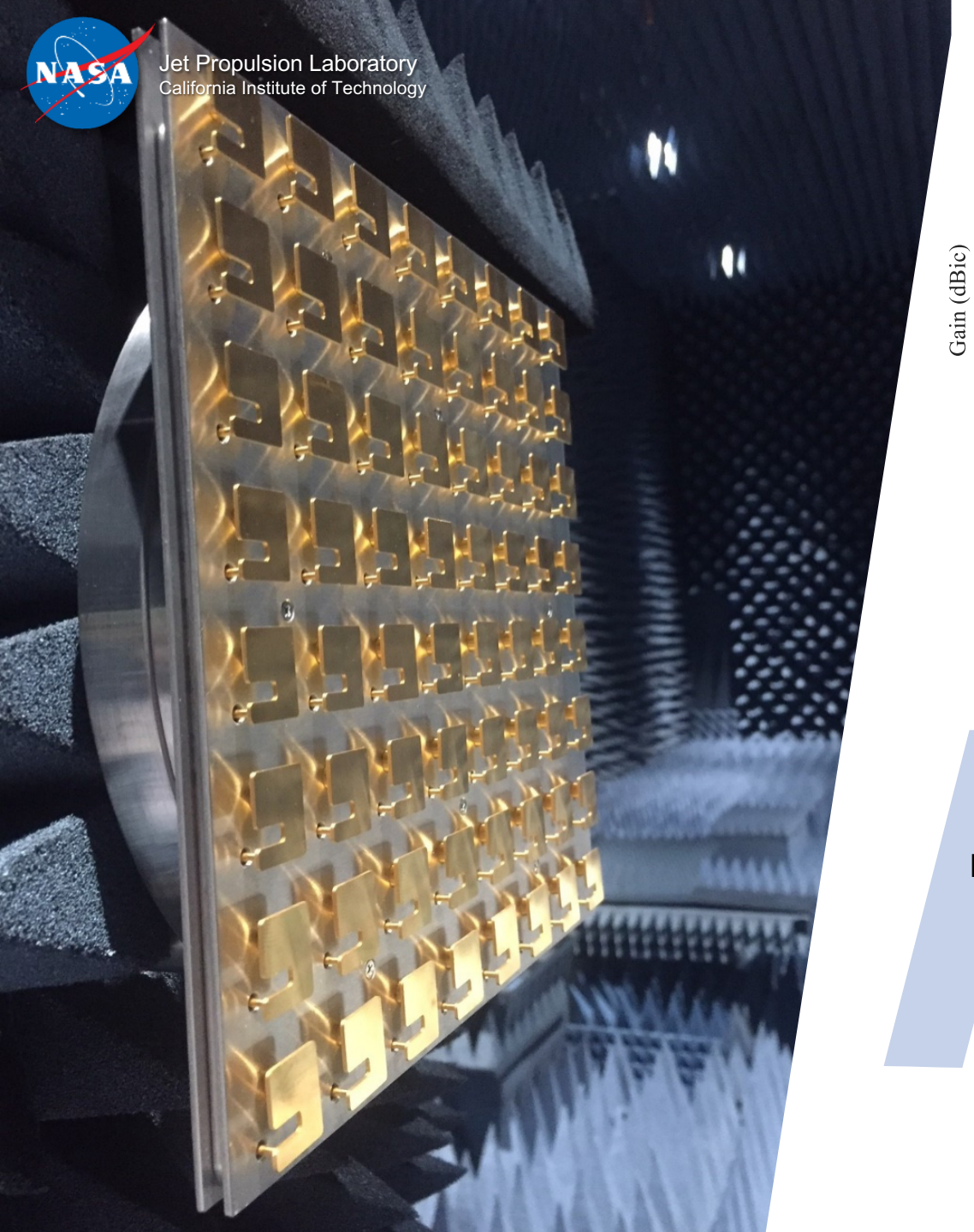


Subarray and Radiation test (TID and iESD):

- Accelerated test (i.e. 90 days in 8hours) was performed in the Dynamitron at JPL at -170C on the 8x8 patch array for TID (3Mrad with RDF = 2) and iESD.
- The iESD environment was defined for the last 90days. The average charging rate for the total 90.5 days is **3.82 pA/cm^3 (**with RDF = 2**)**.
- No harmful discharges were measured or defects observed.
- S_{11} was measured before after radiation to assess whether there are any damage caused by potential discharges.







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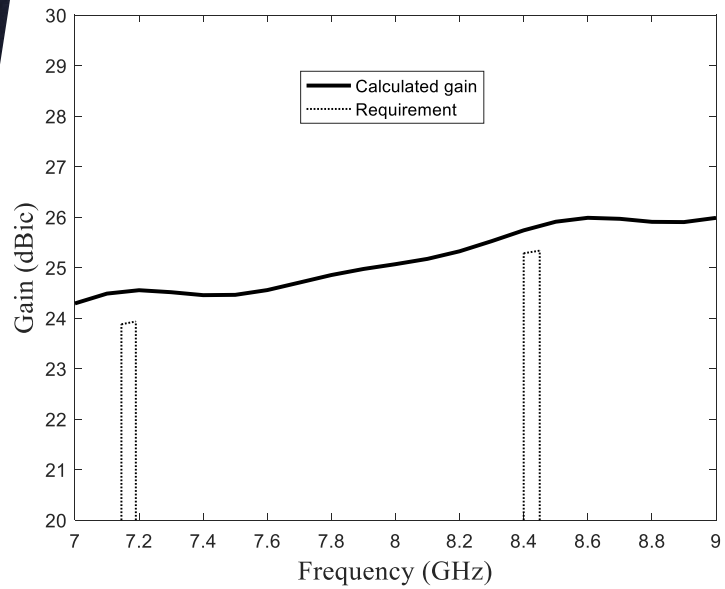
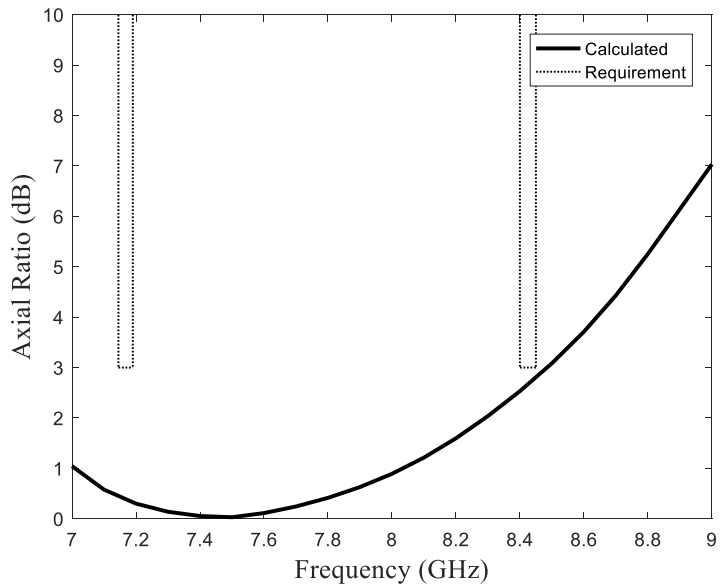
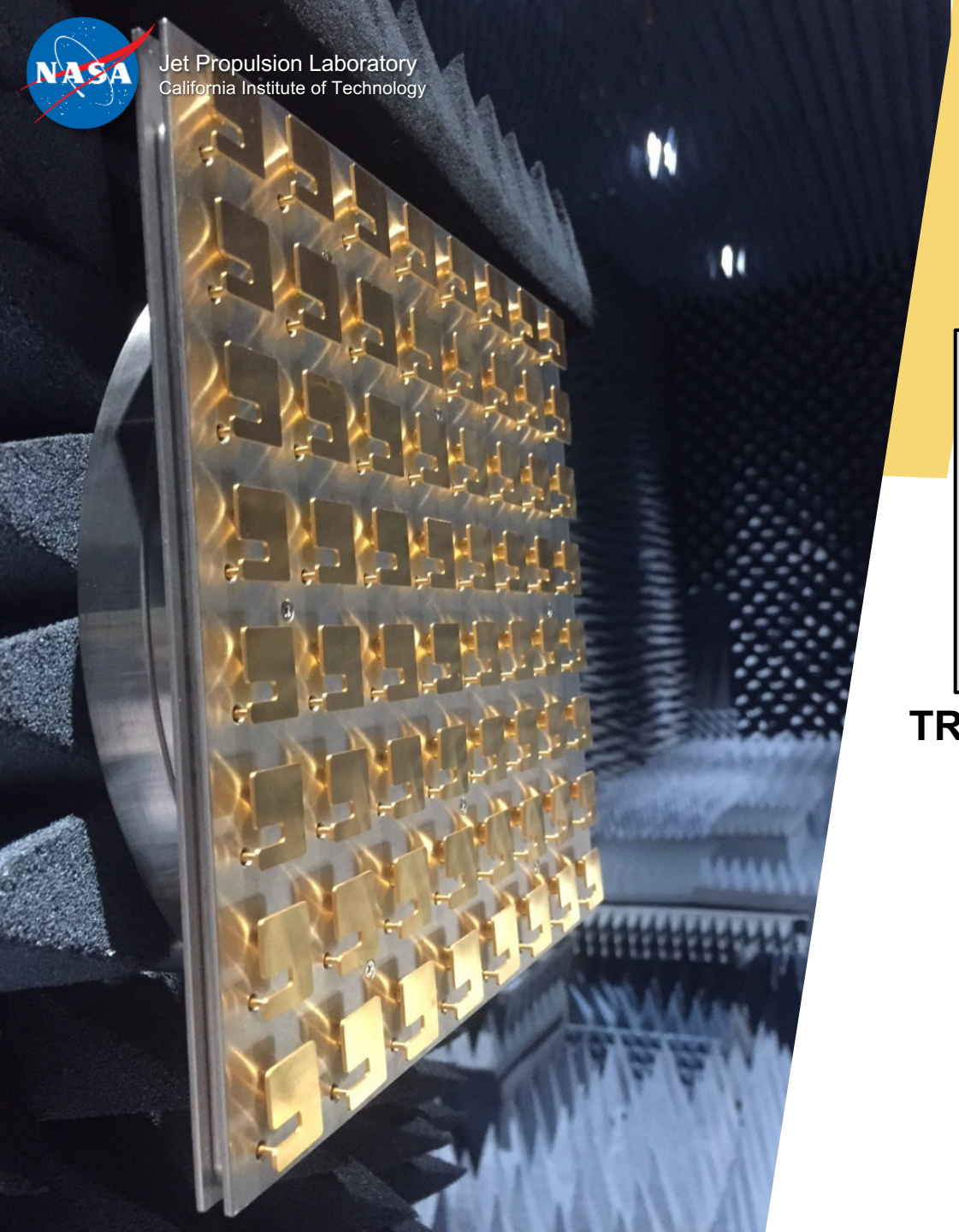


Gain over frequency



Axial ratio over frequency

Frequency (GHz)	Directivity (dBi)		Gain (dBic)		Axial Ratio (dB)	
	Calc.	Meas.	Calc.	Meas.	Calc.	Meas.
7.1675	24.9	24.9	24.5	24.1±0.4	0.3	0.3
8.425	26.0	26.0	25.6	25.3±0.4	2.7	2.2



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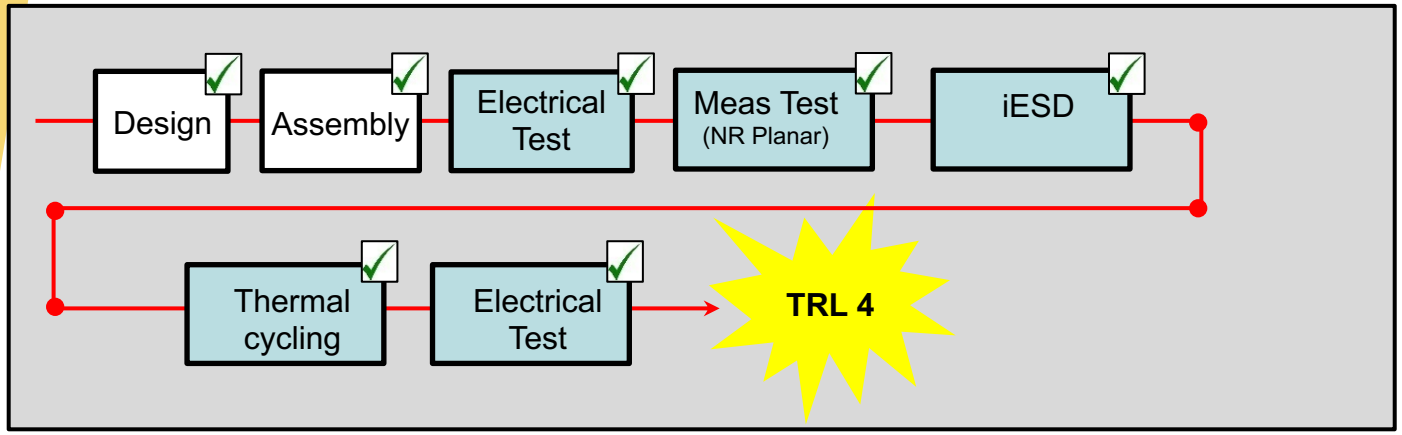
8×8 PATCH ARRAY HAS REACHED TRL 4 AND PASSED ALL CRITICAL TESTS TO SURVIVE AND OPERATE ON EUROPA

8 x 8 Patch Element Antenna



TRL 1 **TRL 4**

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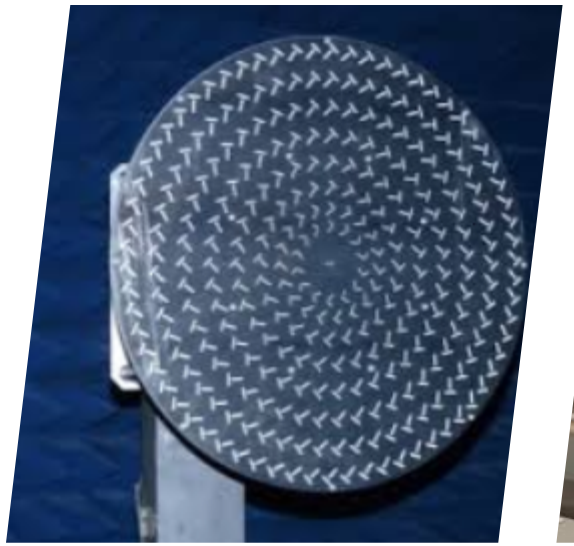
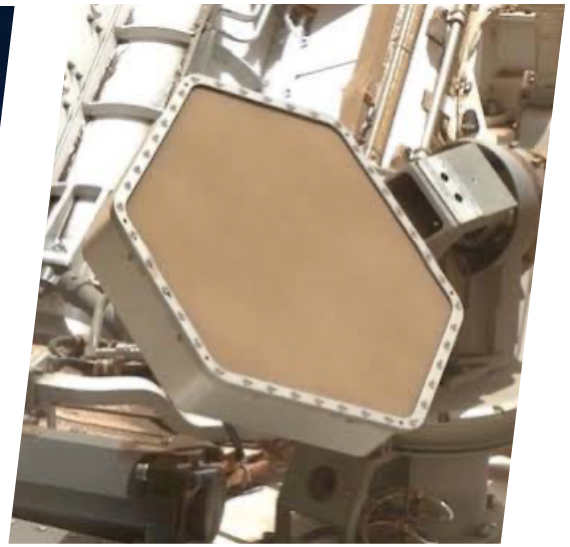
THE EUROPA ANTENNA EXEEDS THE PERFORMANCE OF ANY ANTENNA FLOWN BEFORE BY NASA

	Aperture Efficiency (%)	Gain (dBic)	Area (cm^2)	HPBW (degree)	Mass (kg)
RLSA	37 / 18	25.3 / 23.5	1256.6 40cm diameter	6.0 / 5.1	1.24
MSL	49 / 44	22.9 / 23.8	551.2	10.0 / 8.4	1.4
MER	25 / 49	20.5 / 24.8	615.8	10.0 / 8.4	1.1
This work	84/ 80	24.1 / 25.3	428.5 20.7cm×20.7cm	10.4 / 8.7	0.5



RLSA



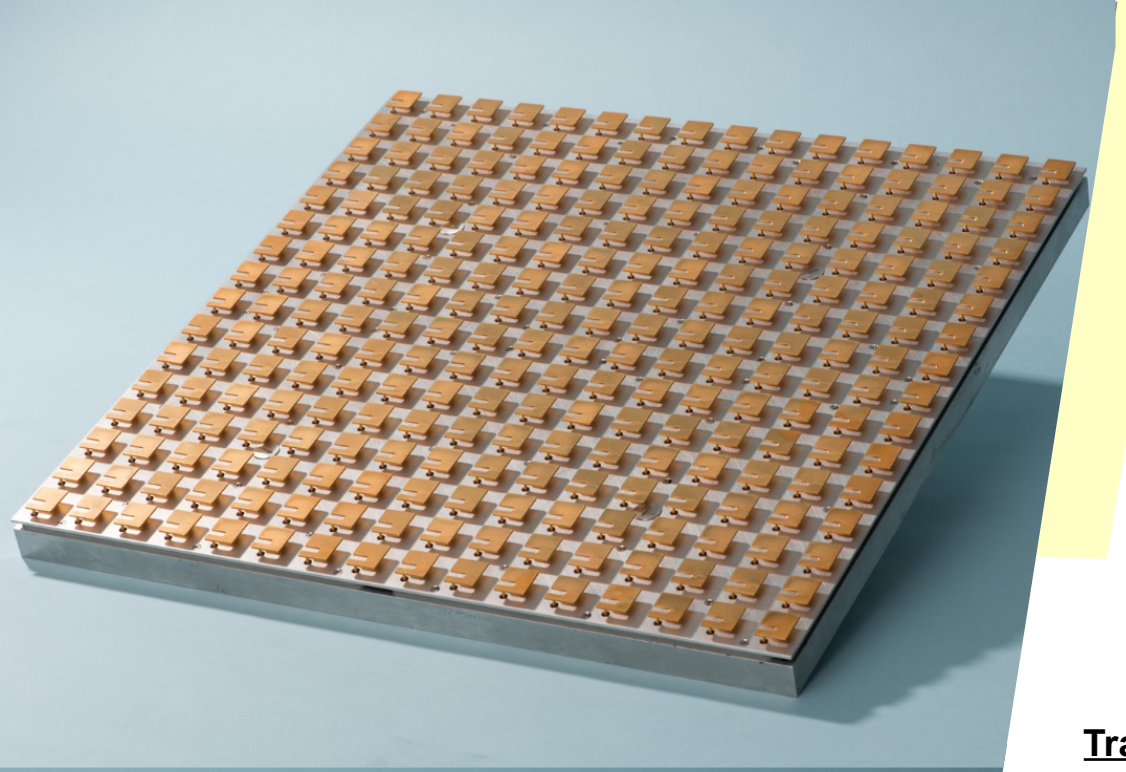
MSL

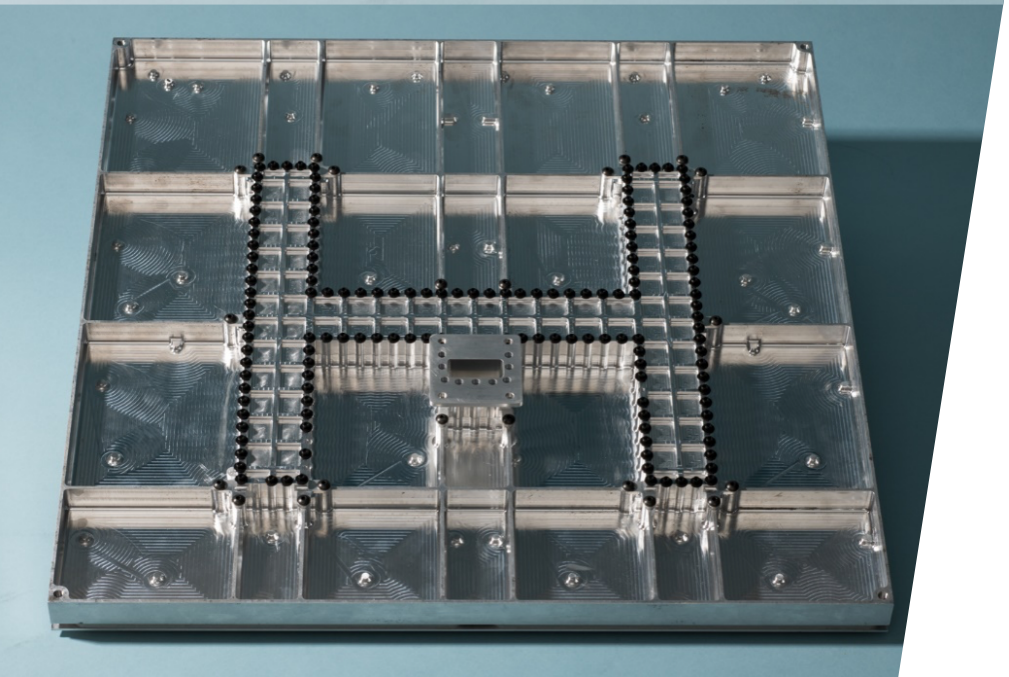
SMALLER

MORE EFFICIENT

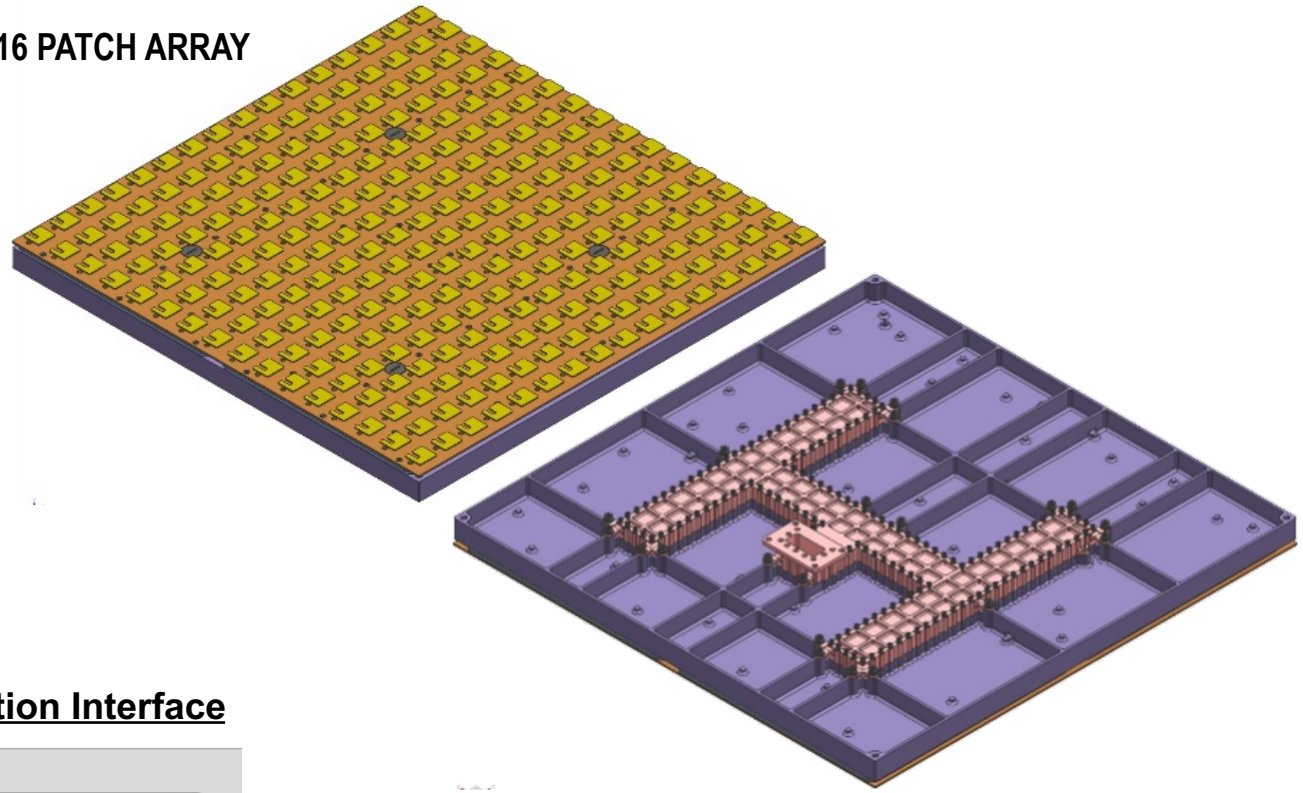
RELAXES POINTING

HIGHER POWER

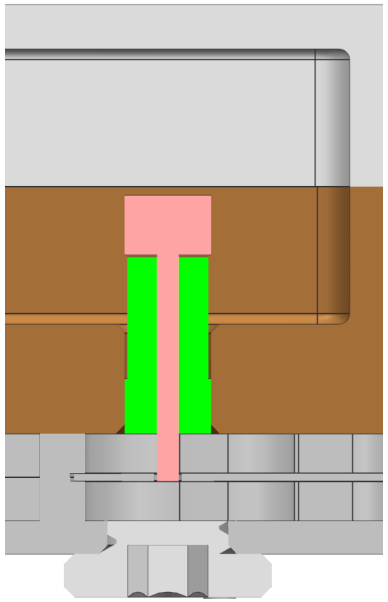




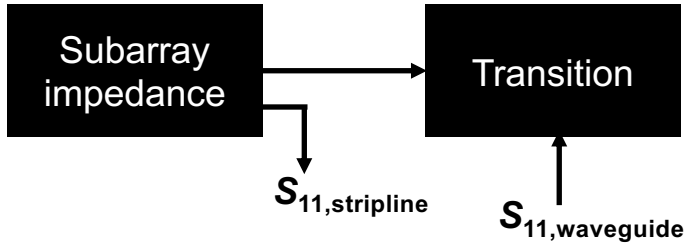
16×16 PATCH ARRAY

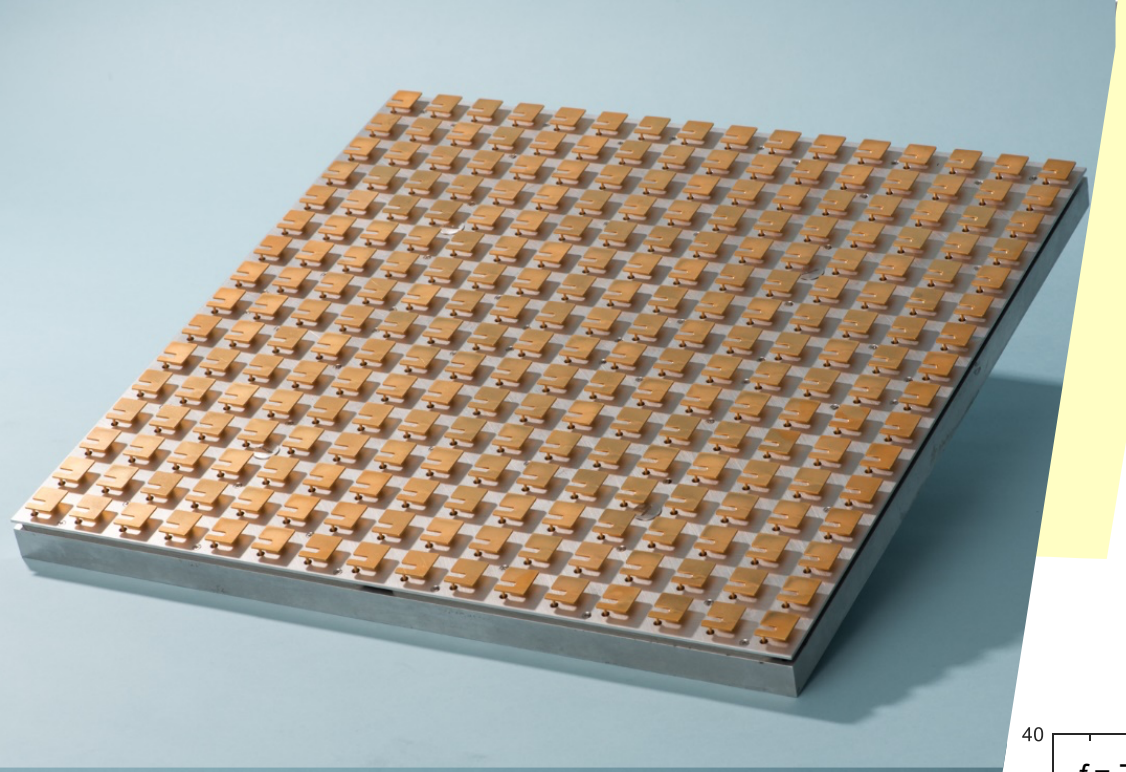


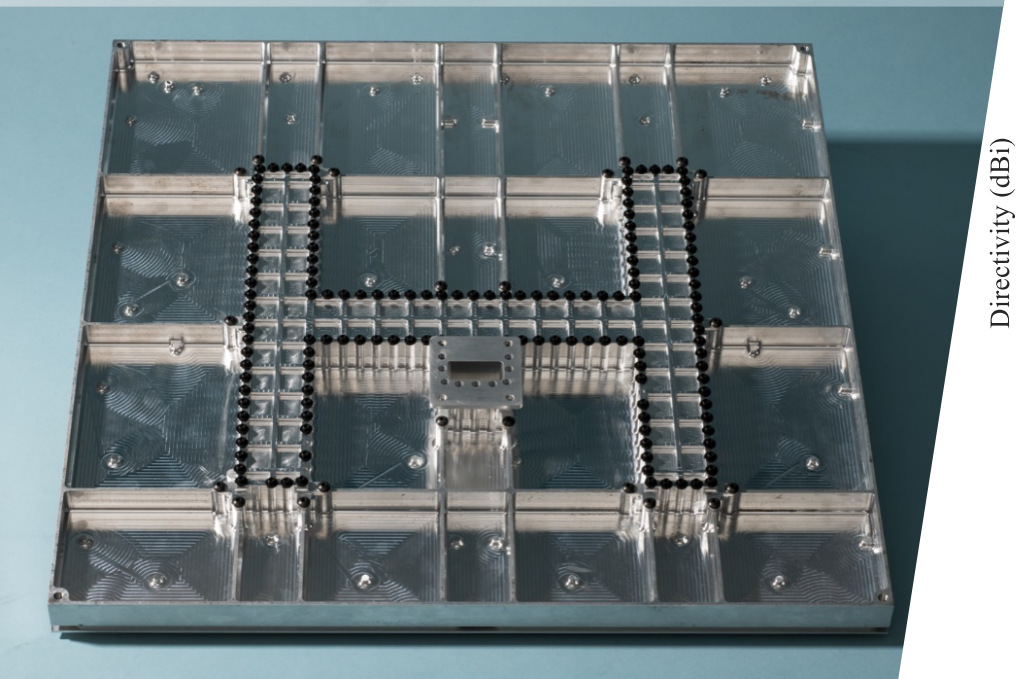
Transition Interface



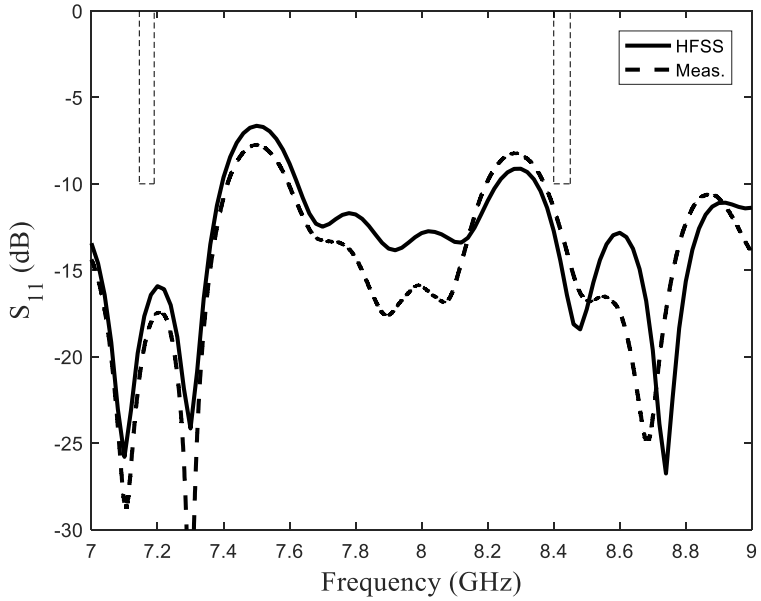
Design of transition

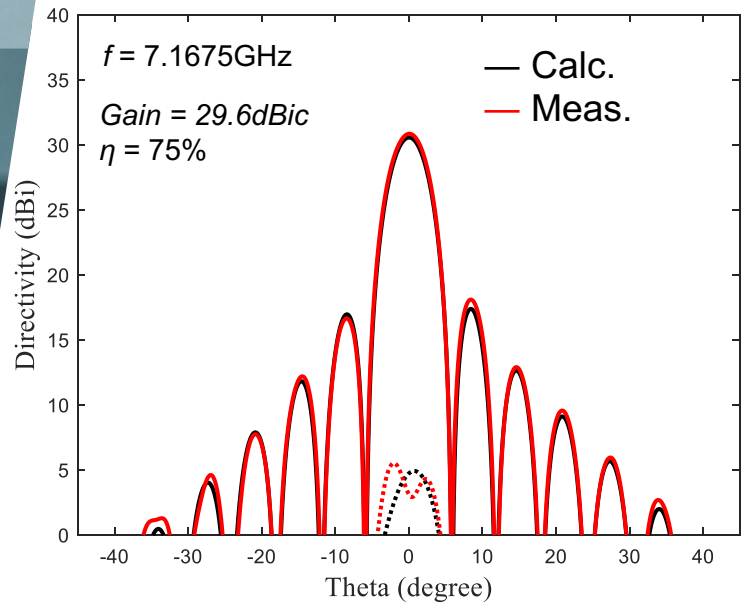


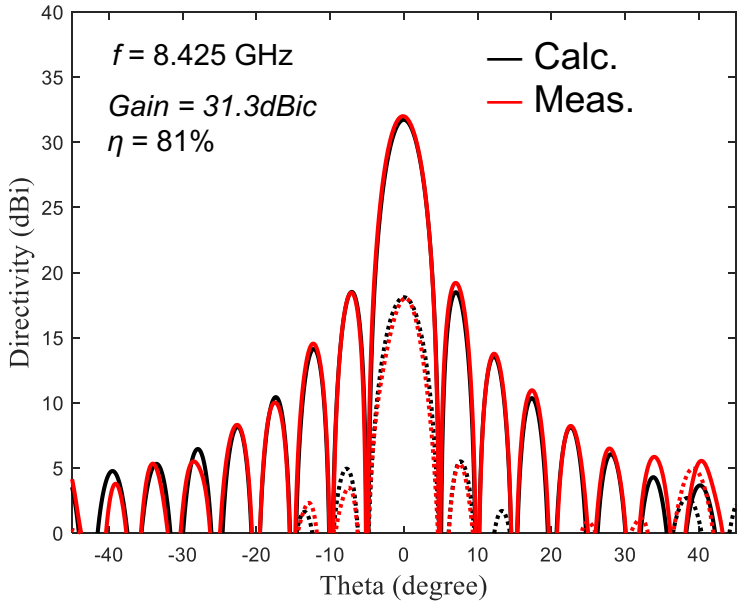


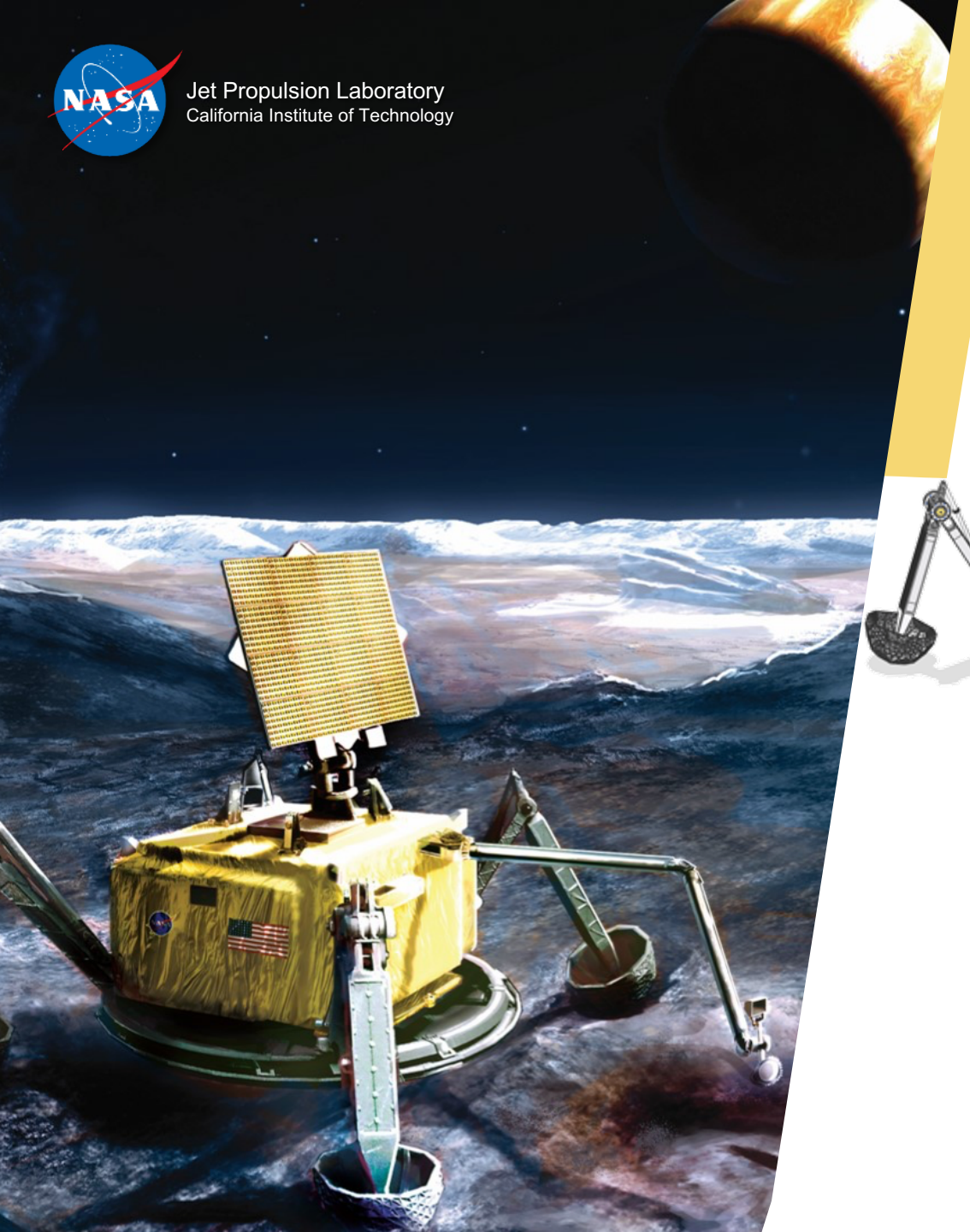


16×16 PATCH ARRAY
PERFORMANCE SUCCESFULLY
TESTED FROM -170C to +110C

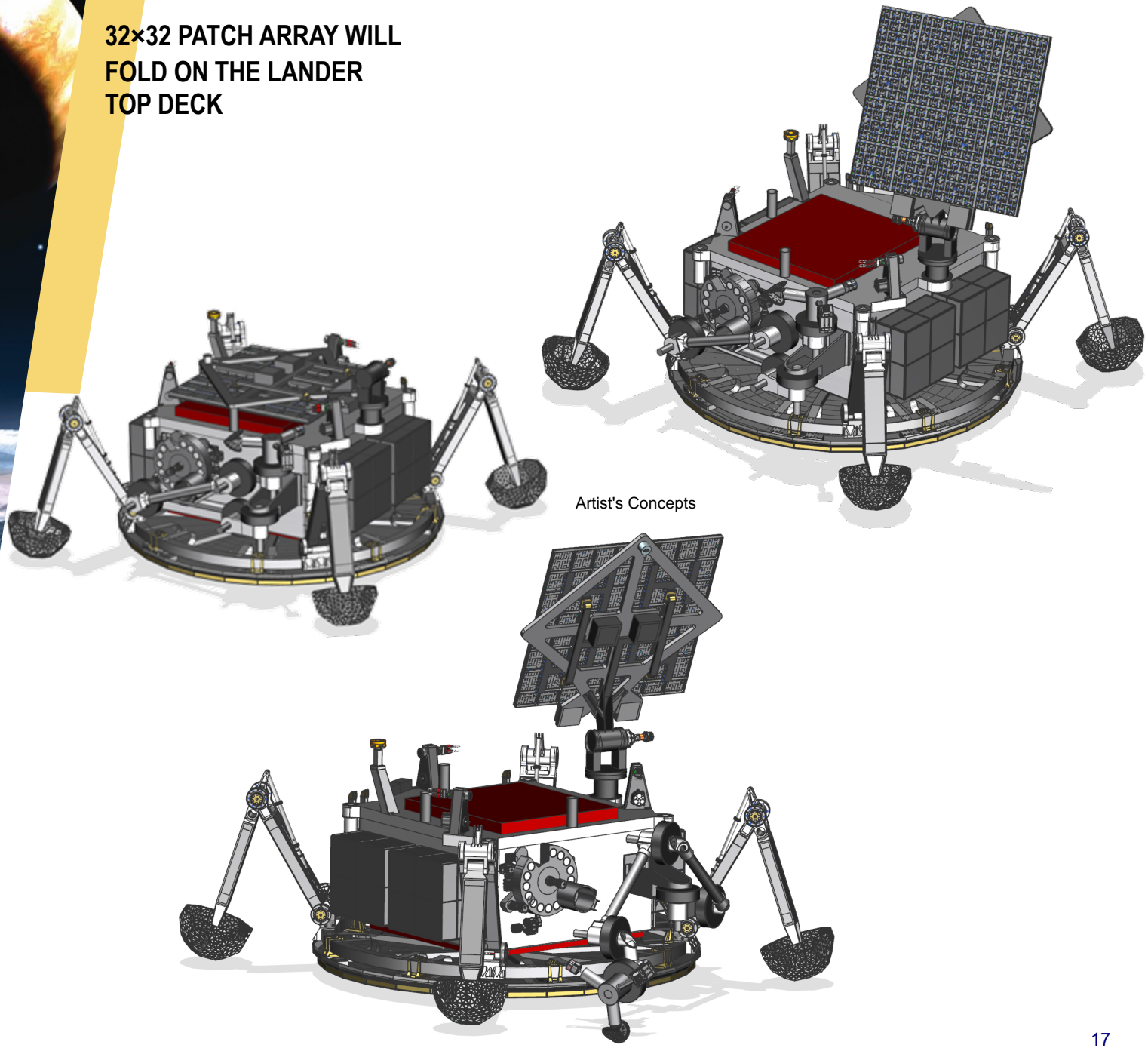




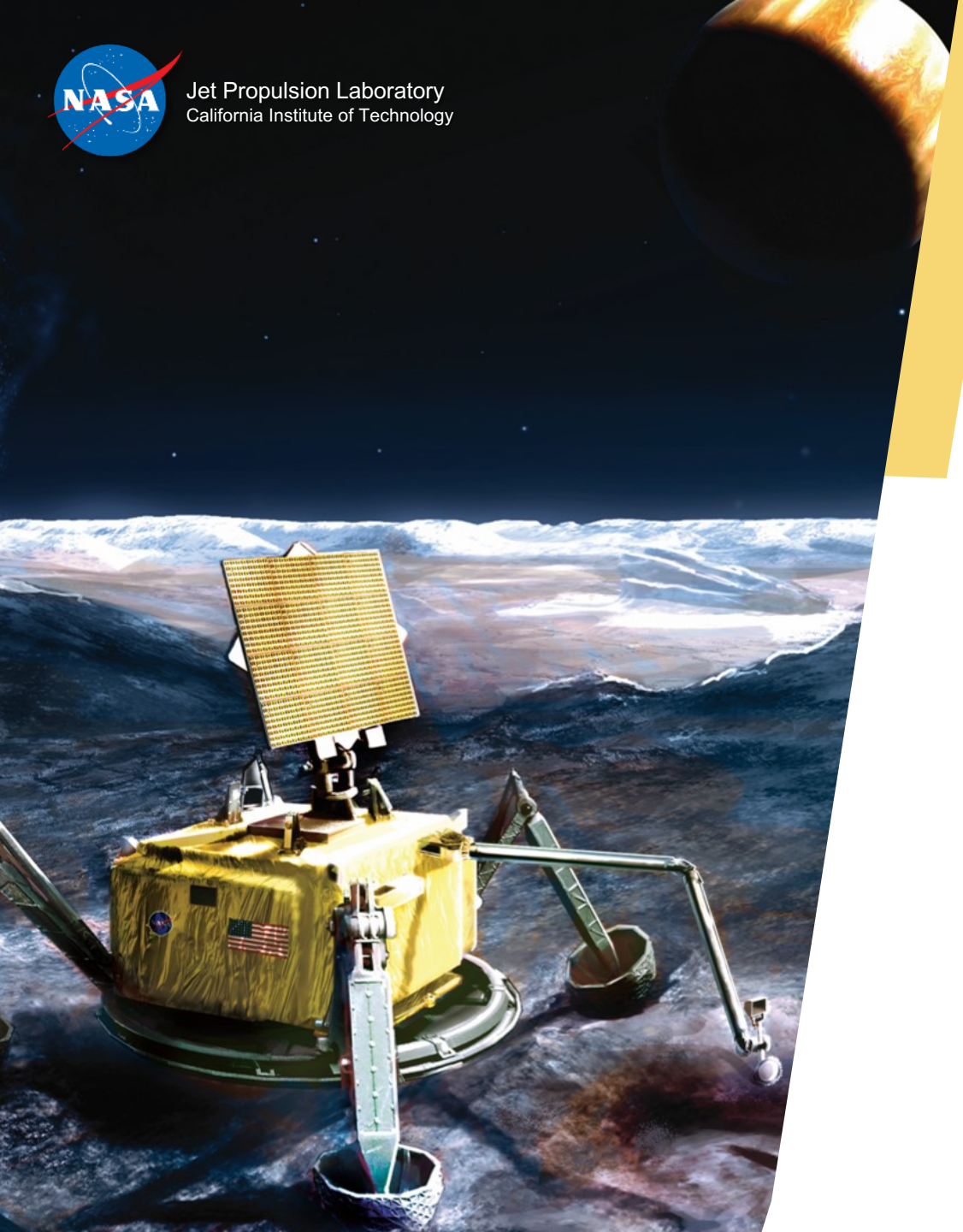




32×32 PATCH ARRAY WILL FOLD ON THE LANDER TOP DECK



Artist's Concepts



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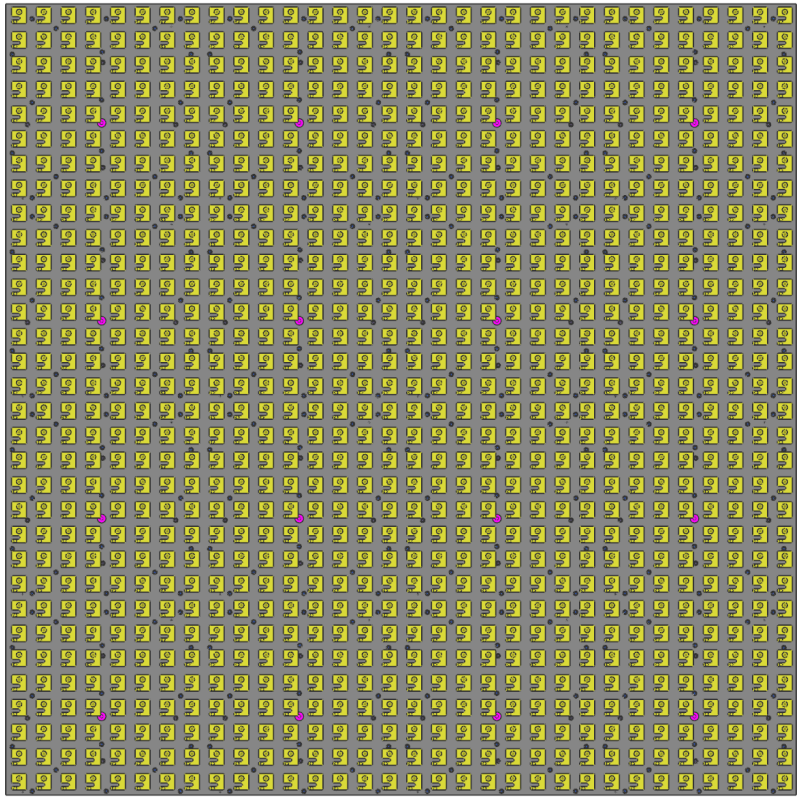
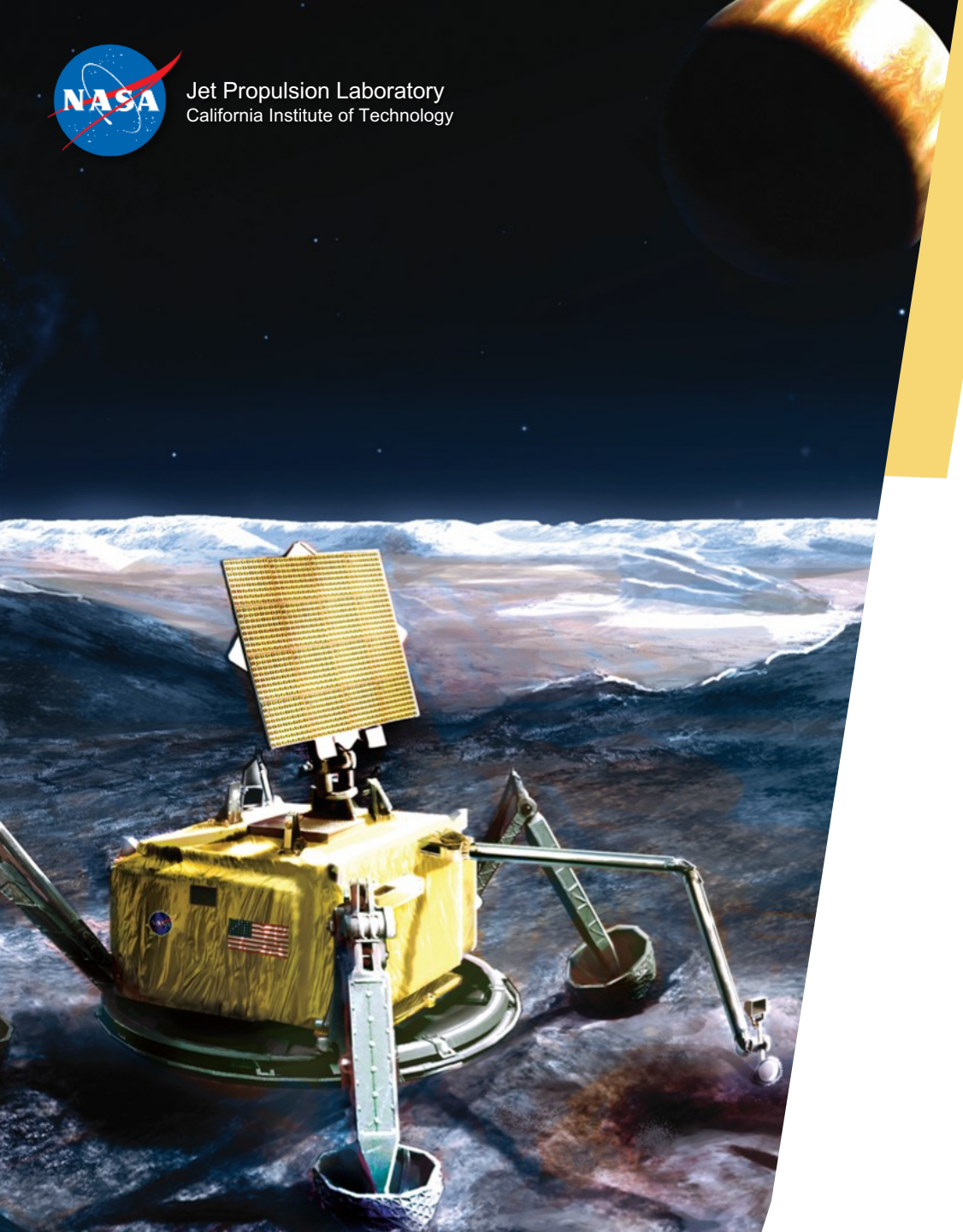
32×32 PATCH ARRAY IS CURRENTLY UNDER FABRICATION AND WILL BE QUALIFIED TO ACHIEVE TRL 6

Front View

32x32 Patch Elements on Front Plate. Linear array 25.4mm spacing, both directions.





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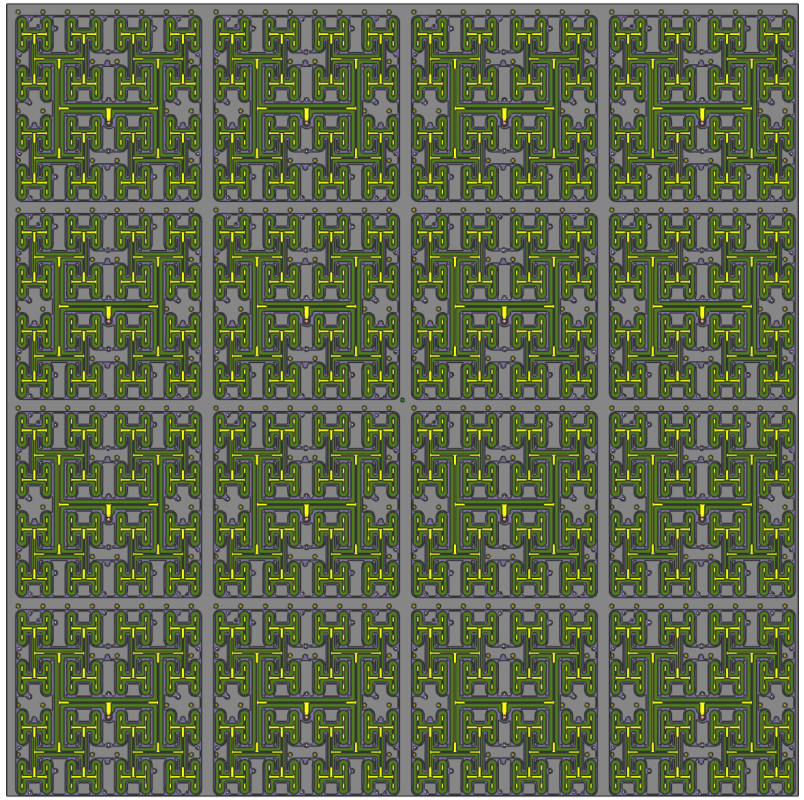
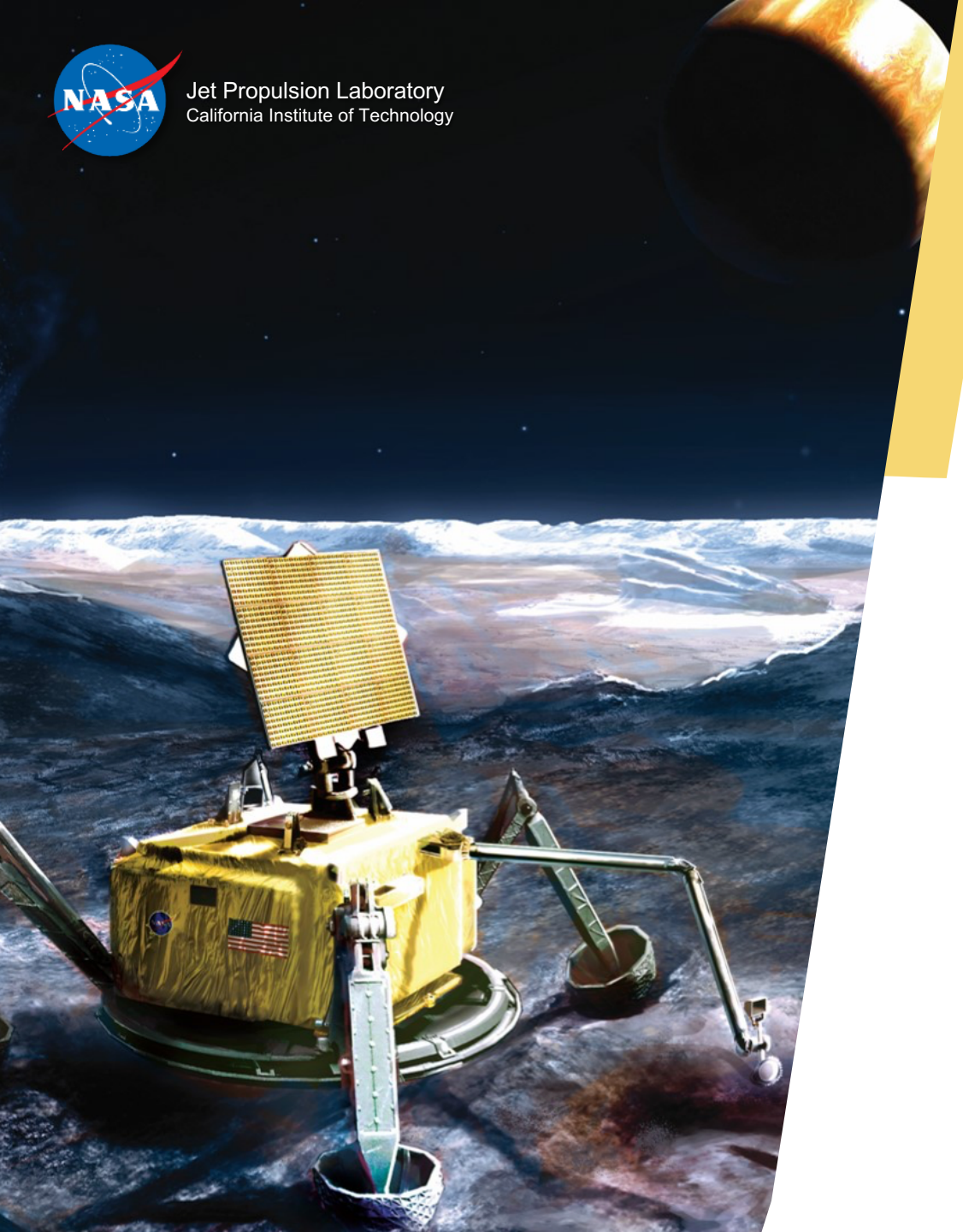
32×32 PATCH ARRAY IS CURRENTLY UNDER FABRICATION AND WILL BE QUALIFIED TO ACHIEVE TRL 6

Back View

4x4 Guides/PWB. Linear array 206.24mm spacing, both directions.





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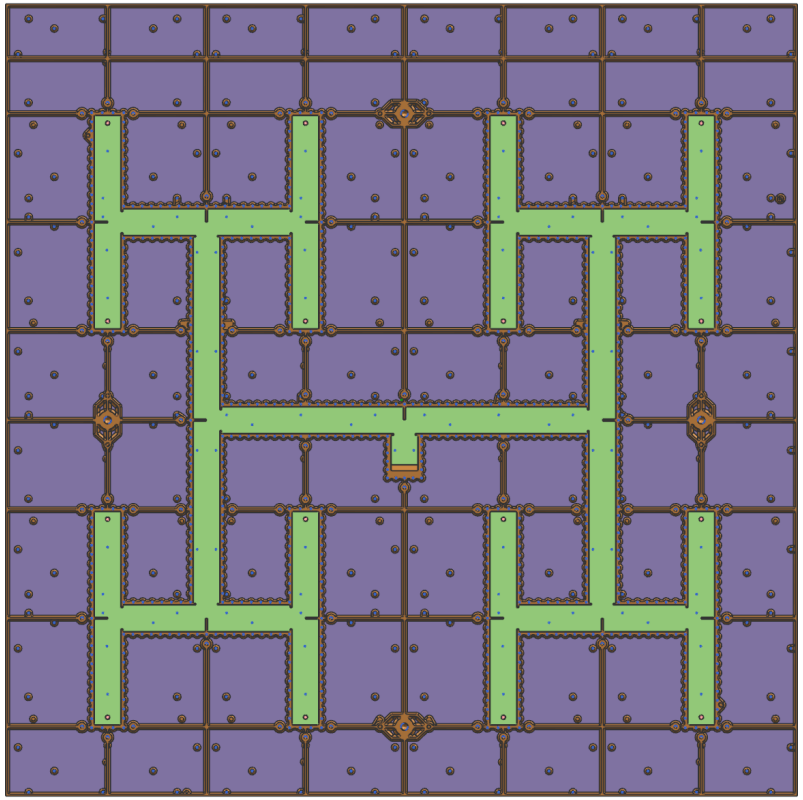
32×32 PATCH ARRAY IS CURRENTLY UNDER FABRICATION AND WILL BE QUALIFIED TO ACHIEVE TRL 6

Back View

Transitions and waveguide connect all sets of Guides/PWB



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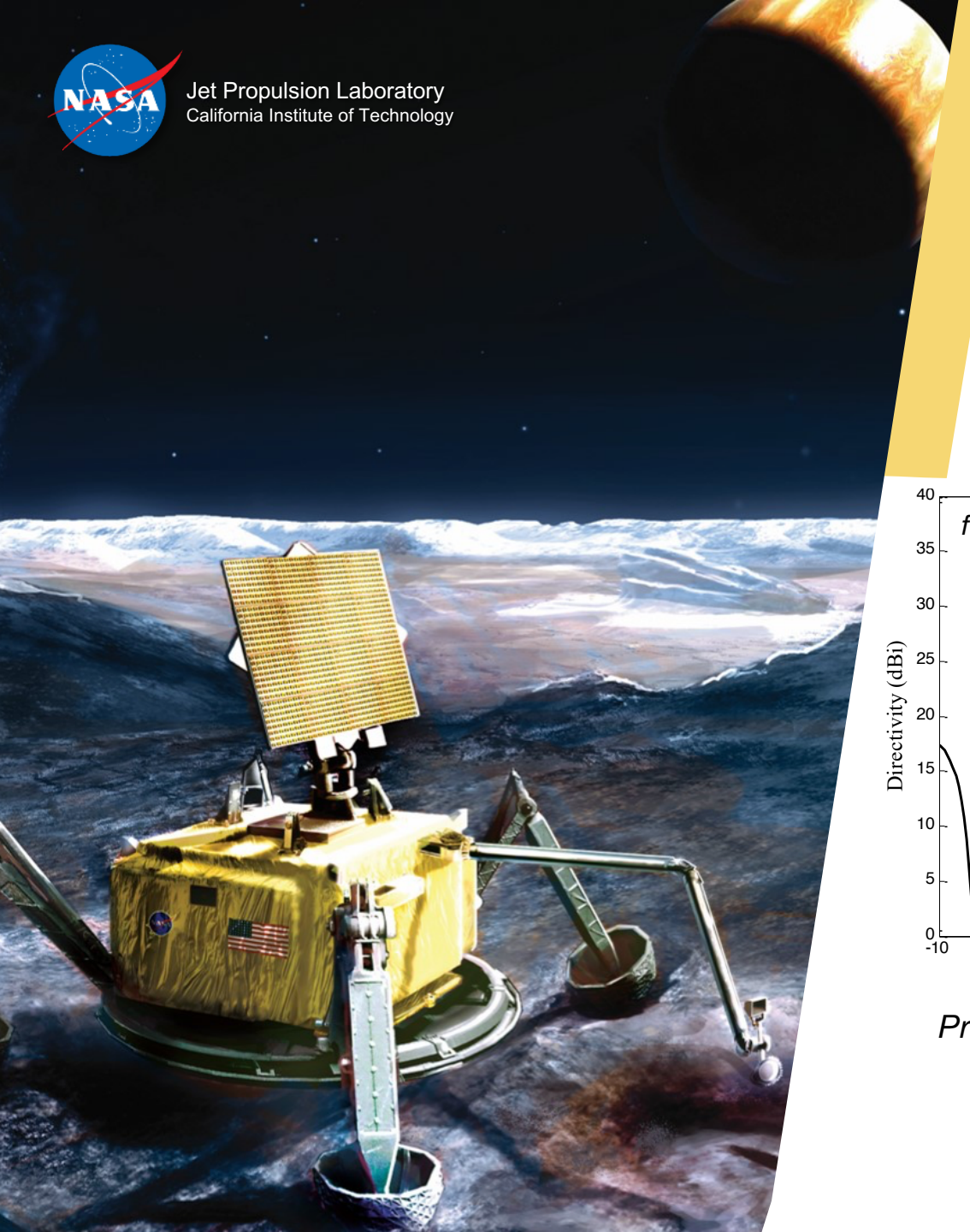
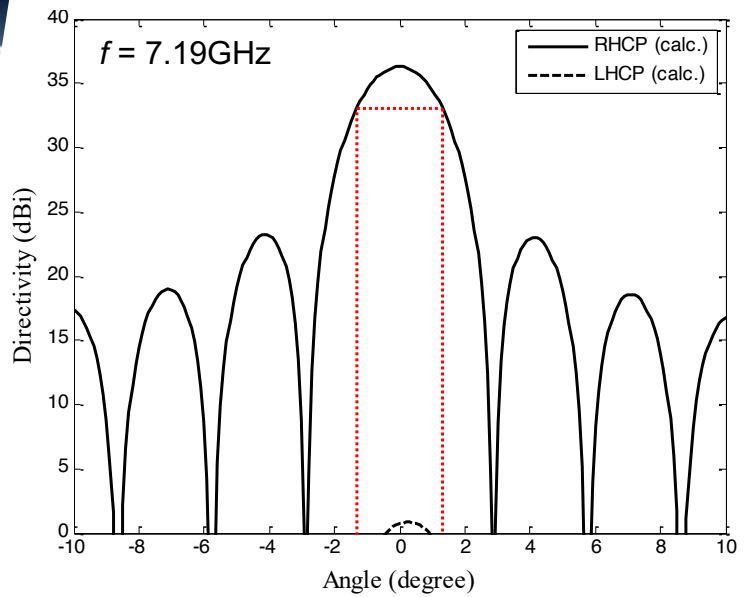
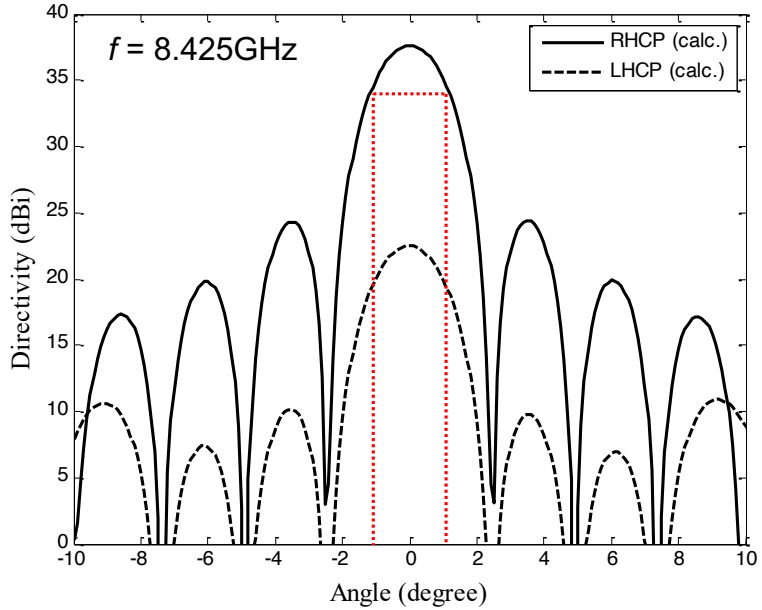


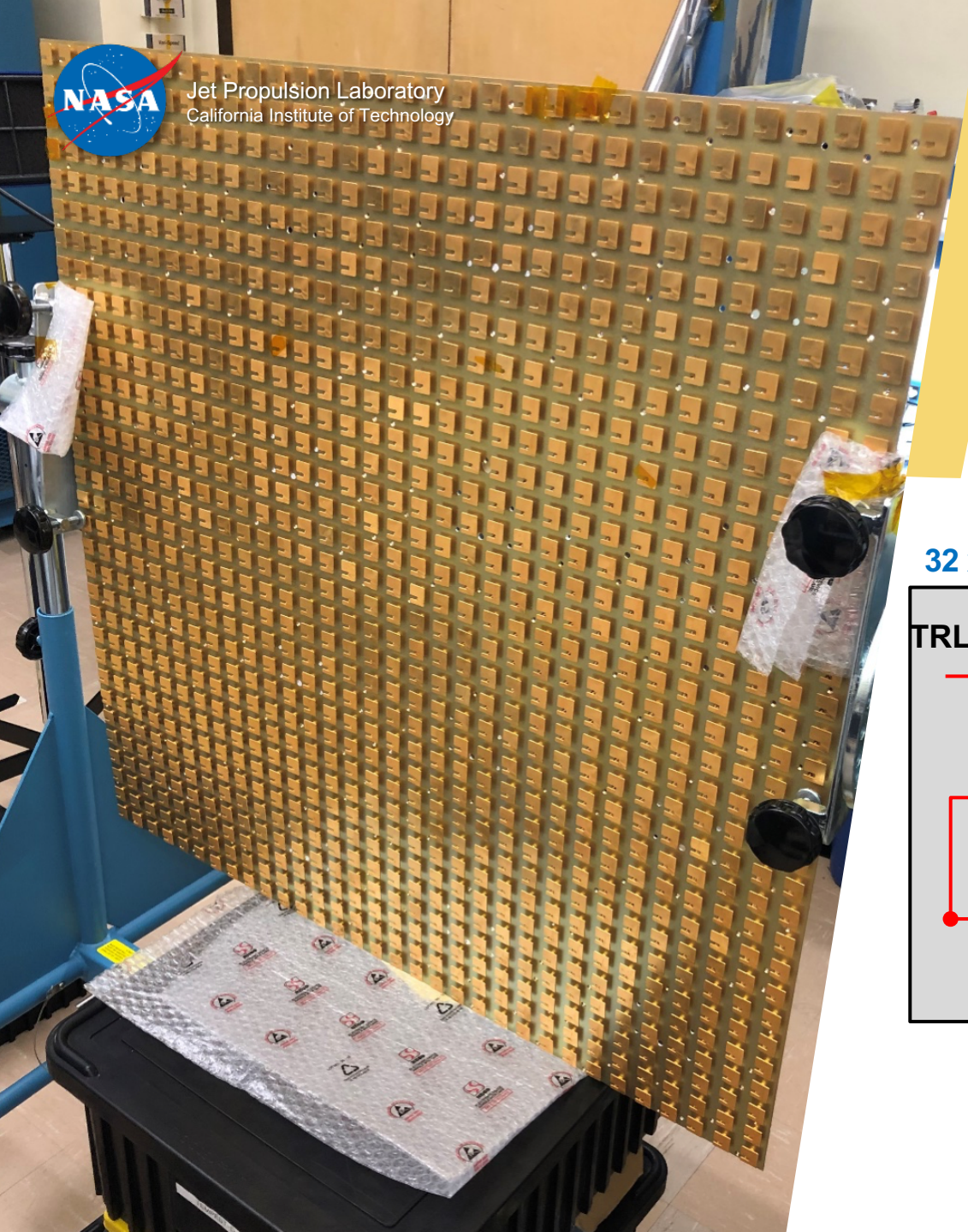
32×32 PATCH ARRAY IS CURRENTLY UNDER FABRICATION AND WILL BE QUALIFIED TO ACHIEVE TRL 6



Predicted gain = 36.0dBic

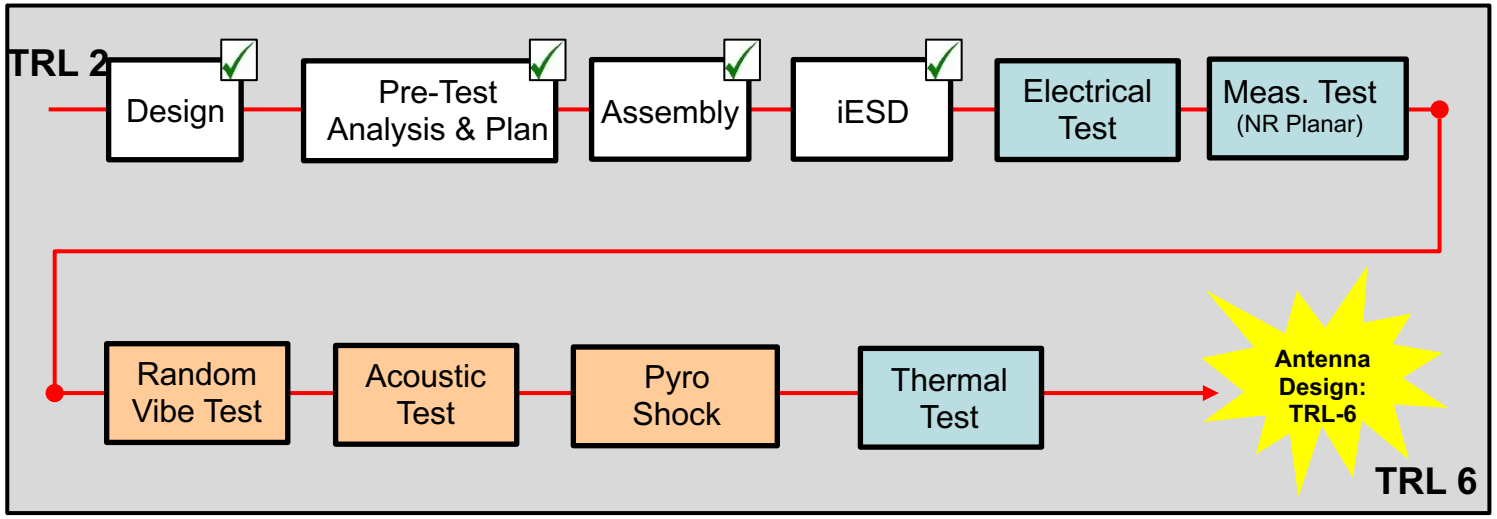


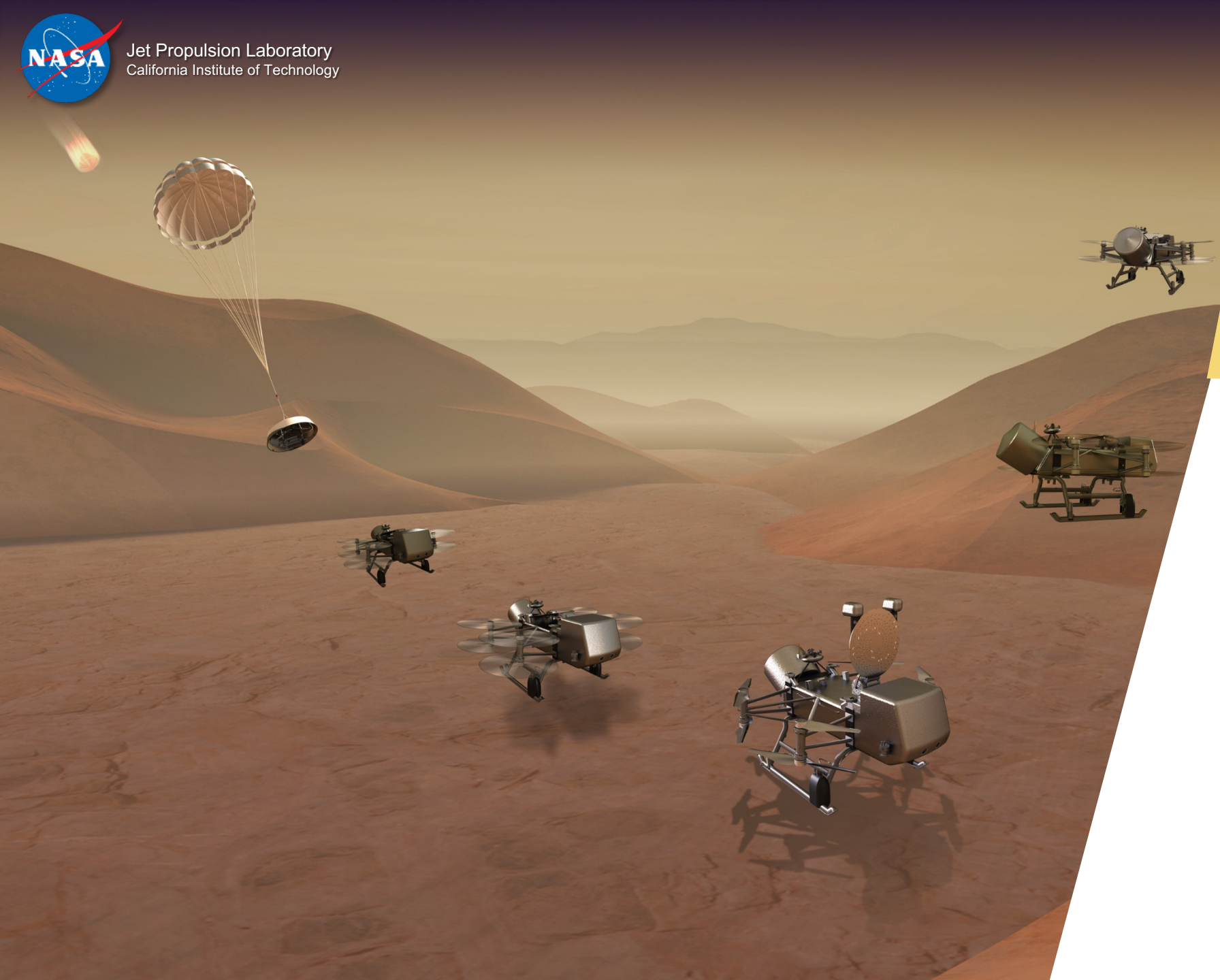
Predicted gain = 37.5dBic



32×32 PATCH ARRAY IS CURRENTLY UNDER FABRICATION AND WILL BE QUALIFIED TO ACHIEVE TRL 6

32 x 32 Patch Element Antenna





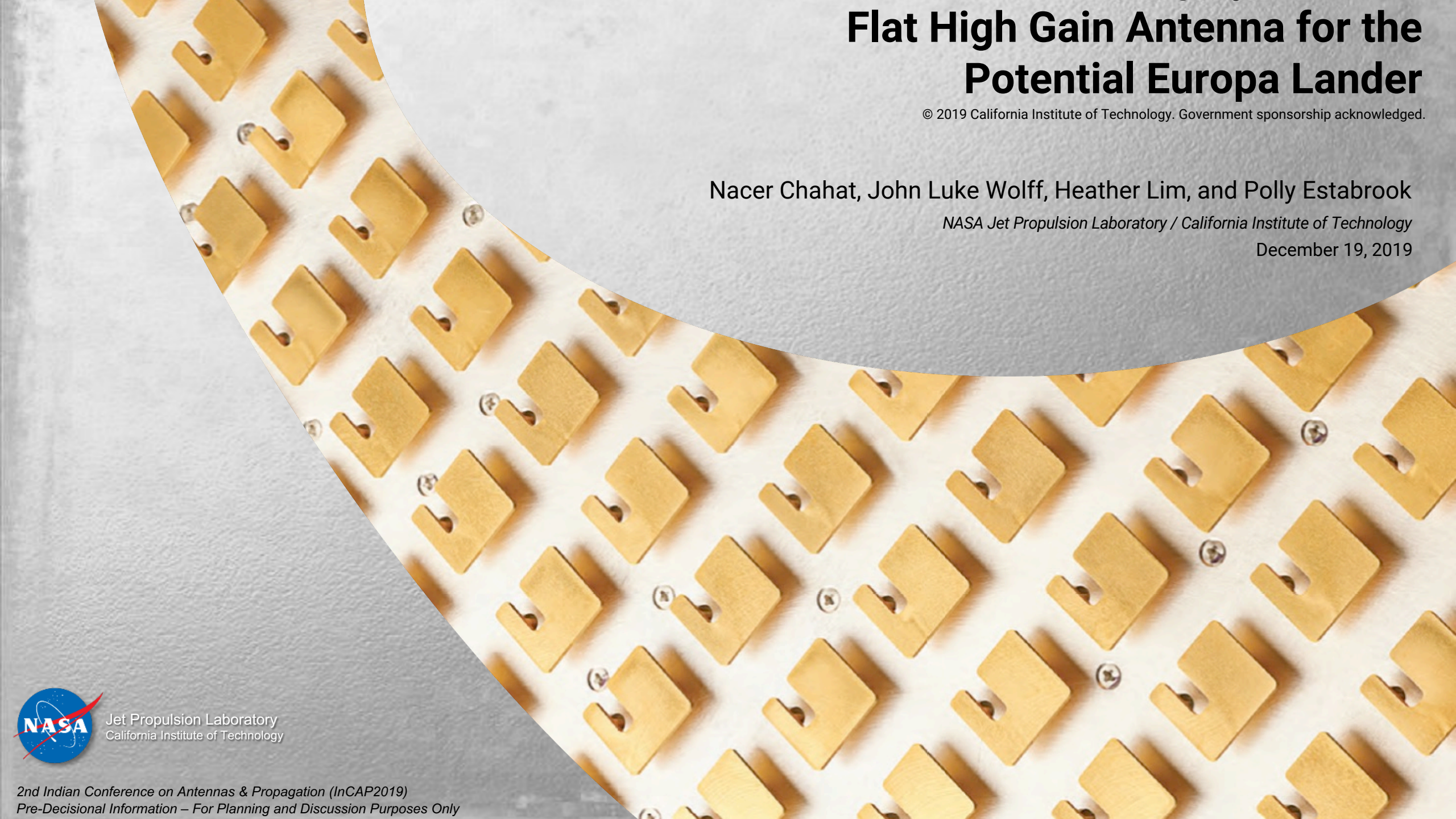
DTE COMMUNICATION CAN NOW BE DONE FROM LARGE DISTANCES AND IN HOSTILE ENVIRONMENTS. MORE MISSIONS WILL USE DTE ONLY COMMUNICATION LINKS.

Flat High Gain Antenna for the Potential Europa Lander

Nacer Chahat, John Luke Wolff, Heather Lim, and Polly Estabrook

NASA Jet Propulsion Laboratory / California Institute of Technology

December 19, 2019



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2nd Indian Conference on Antennas & Propagation (InCAP2019)
Pre-Decisional Information – For Planning and Discussion Purposes Only